Chapter 5

Water Monitoring Programs

Duane Rueppel
Richard A. Brown
Chris G. Campbell
Allen Grayson
Henry E. Jones
Michael A. Revelli

Lawrence Livermore National Laboratory monitors a multifaceted system of waters that includes wastewaters, storm water, and groundwater, as well as rainfall and local surface waters. Water systems at the two LLNL sites, the Livermore site and Site 300, operate differently. For example, the Livermore site is serviced by publicly owned treatment works but Site 300 is not, resulting in different methods of treating and disposing of sanitary wastewater the two sites. Many drivers determine the appropriate methods and locations of the various water monitoring programs, as described below.

In general, water samples are collected according to written, standardized procedures appropriate for the medium (Woods

2005). Sampling plans are prepared by the LLNL network analysts who are responsible for developing and implementing monitoring programs or networks. Network analysts decide which analytes are sampled (see **Appendix C**) and at what frequency, incorporating any permit-specified analyses. Except for analyses of certain sanitary sewer and retention tank analytes, analyses are usually performed by off-site, California-certified contract analytical laboratories.

5.1 Sanitary Sewer Effluent Monitoring

In 2006, the Livermore site discharged an average of 1.04 million liters per day (million L/day)) (271,739 gallons per day [gal/day]) of wastewater to the City of Livermore sewer system, or 3.7% of the total flow into the City's system. This volume includes wastewater generated by Sandia National Laboratories/ California (Sandia/California) and a very small quantity from Site 300 (227,118 L [60,000 gal]). In 2006, Sandia/California generated approximately 11% of the total effluent discharged from the Livermore outfall. Wastewater from Sandia/California and Site 300 is discharged to the LLNL collection system and combined with LLNL sewage before it is released at a single point to the municipal collection system (see **Figure 5-1**).

LLNL's wastewater contains both sanitary sewage and process wastewater and is discharged in accordance with permit requirements and the City of Livermore Municipal Code, as discussed below. Most of the process wastewater generated at the Livermore site is

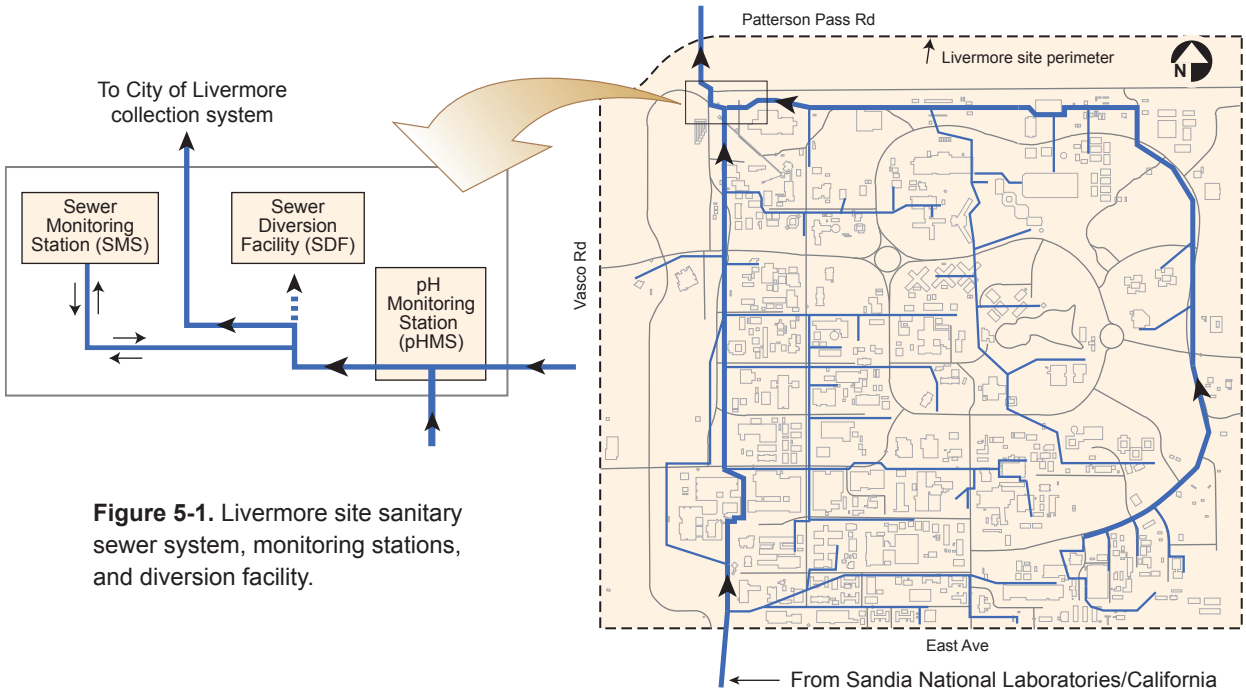

Figure 5-1. Livermore site sanitary sewer system, monitoring stations, and diversion facility.

collected in various retention tanks and discharged to LLNL's collection system under prior approval from LLNL's Water Guidance and Monitoring Group (WGMG) Waste Discharge Authorization Record (WDAR) approval process.

5.1.1 Livermore Site Sanitary Sewer Monitoring Complex

LLNL's sanitary sewer discharge permit (Permit 1250, 2005/2006 and 2006/2007) requires continuous monitoring of the effluent flow rate and pH. Samplers at the Sewer Monitoring Station (SMS) (see **Figure 5-1**) collect flow-proportional composite samples and instantaneous grab samples that are analyzed for metals, radioactivity, toxic chemicals, and water-quality parameters. In addition, as a best management practice, the outflow to the municipal collection system is sampled continuously and analyzed in real time for conditions that might cause upset or pass through to the Livermore Water Reclamation Plant (LWRP) treatment process or otherwise impact the public welfare. The effluent is analyzed continuously for flow, pH, regulated metals, and gamma radioactivity. If concentrations above warning levels are detected, the site effluent is automatically diverted to the Sewer Diversion Facility (SDF) (see **Figure 5-1**) and an alarm is registered at the LLNL Fire Dispatcher's Station, which is attended 24 hours a day, 7 days a week. The monitoring system provides a continuous check on sewage effluent, and the LWRP is notified of contaminant alarms. Trained LLNL staff respond to all alarms to evaluate the cause and take appropriate action.

In addition to the continuous monitoring at the SMS, LLNL monitors pH at the upstream pH Monitoring Station (pHMS) (see **Figure 5-1**). The pHMS monitors pH continuously during peak flow hours (7 a.m. to 7 p.m. during the workweek) and diverts pH discharges outside the permit range of 5 to 10 to the SDF. The pHMS duplicates the pH monitoring and diversion capabilities of the SMS but is able to initiate diversion earlier because it is located farther upstream of the SDF.

LLNL maintains and operates a diversion system that activates automatically when either the SMS continuous monitoring system or the pHMS detects an anomalous condition. For SMS-activated alarms, the SDF ensures that all but the first few minutes of the potentially affected wastewater flow is retained at LLNL, thereby protecting the LWRP and minimizing any potential cleanup. When the SDF is activated by the upstream pHMS for pH excursions, even the first few minutes of affected wastewater flow are retained. Up to 775,000 L (204,733 gal) of potentially contaminated sewage can be held, pending analysis to determine the appropriate handling method. If the diverted effluent meets LLNL's wastewater discharge permit limits, it may be returned to the sanitary sewer. If not, it may be treated at LLNL's Radioactive and Hazardous Waste Management (RHWM) facilities and then released to the sanitary sewer, or shipped for off-site disposal. All diverted sewage in 2006 was returned to the sanitary sewer.

5.1.1.1 Radiological Monitoring Results

Work Smart Standards (WSSs) establish the standards of operation at LLNL (see **Chapter 2**), including the standards for sanitary sewer discharges. Some of the standards for radioactive material releases are contained in complementary (rather than overlapping) sections of the U.S. Department of Energy (DOE) Order 5400.5, Radiation Protection of the Public and the Environment, and Title 10 of the *Code of Federal Regulations*, Part 20 (10 CFR Part 20).

The WSSs for sanitary sewer discharges from DOE Order 5400.5 include the criteria DOE has established for the application of best available technology to protect public health and minimize degradation of the environment. These criteria (the derived concentration guides, or DCGs) limit the concentration of each radionuclide discharged to publicly owned treatment works. If the measured monthly average concentration of a radioisotope exceeds its concentration limit, LLNL is required to improve discharge control measures until concentrations are again below the DOE limits.

The WSSs from 10 CFR Part 20 for sanitary sewer discharge numerical limits include the following annual discharge limits for radioactivity: tritium, 185 gigabecquerel (GBq) (5 curies [Ci]); carbon-14, 37 GBq (1 Ci); and all other radionuclides combined, 37 GBq (1 Ci). The 10 CFR Part 20 limit on total tritium activity dischargeable during a single year (185 GBq [5 Ci]) takes precedence over the DOE Order 5400.5 concentration-based limit for tritium for facilities that generate wastewater in large volumes, such as LLNL. In addition to complying with the 10 CFR Part 20 annual mass-based discharge limit for tritium and the DOE monthly concentration-based discharge limit for tritium, LLNL also complies with the daily effluent concentration-based discharge limit for tritium established by LWRP for LLNL in 1999. The LWRP limit is smaller by a factor of 30 than the DOE monthly limit and the limits are therefore essentially equivalent, but the LWRP limit is more stringent in the sense that it is daily rather than annual. The radioisotopes with the potential to be found in sanitary sewer effluent at LLNL and their discharge limits are discussed below. All analytical results are provided in **Appendix B**, **Section B.3**.)

Table 5-1. Estimated total radioactivity in LLNL sanitary sewer effluent, 2006.

Radioactive emitter	Estimate based on effluent activity (GBq)	Limit of sensitivity (GBq)
Tritium	19.9	1.01
Gross alpha sources	0.02	0.06
Gross beta sources	0.32	0.15

LLNL determines the total radioactivity contributed by tritium, gross alpha emitters, and gross beta emitters from the measured radioactivity in the monthly effluent samples. The 2006 combined release of alpha and beta sources was 0.34 GBq (0.01 Ci), which is 0.9% of the corresponding 10 CFR Part 20 limit (37 GBq [1.0 Ci]). The combined total is the sum of the alpha and beta results shown in **Table 5-1**. The tritium total was 19.9 GBq (0.54 Ci), which is 11% of the 10 CFR Part 20 limit (185 GBq [5 Ci]).

Discharge limits and a summary of the measurements of tritium in the sanitary sewer effluent from LLNL and LWRP are presented in **Table 5-2**. The total monthly activity is calculated by multiplying each monthly concentration by the total flow volume over which

Table 5-2. Monitoring results and discharge limits for tritium in sanitary sewer effluents, LLNL and LWRP, 2006.

		Daily (Bq/mL)		Monthly (Bq/mL)			Monitoring results as percent of limit	
		Maximum	Median	Maximum	Median	Annual	Maximum	Median
Monitoring results	LLNL	1.502[a]	0.002	0.157[b]	0.019	19.9 GBq		
	LWRP			0.005[c]	0.002			
Discharge limits for LLNL effluent	LWRP permit daily	12					12.5%	0.02%
	DOE annualized[d]					370 Bq/mL	0.042%[e]	0.005%
	10 CFR 20 annual total					185 GBq	11%	

(a) Occurred in September.

(b) Occurred in August. All monthly values above limit of sensitivity are plotted in **Figure 5-2.**

(c) Occurred in August.

(d) DOE annualized discharge limit for application of best available technology, which is five times the derived concentration guide (DCG: ingested water) for each radionuclide released.

(e) Monitoring results as a percentage of limit are calculated using the LLNL maximum monthly sample concentration and the DOE annualized discharge limit.

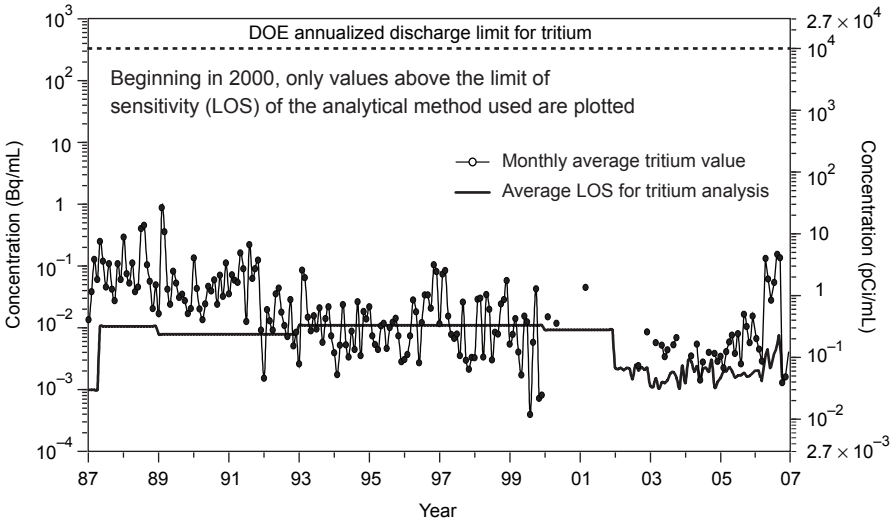

Figure 5-2. Historical tritium concentrations in the Livermore site sanitary sewer effluent and the average level of sensitivity (LOS) for tritium analysis. The DOE annualized discharge limit for application of best available technology is five times the derived concentration guide (DCG: ingested water) for each radionuclide released.

the sample was collected. Per DOE guidance, all total annual results presented in this chapter for radionuclides are calculated by using all analytical results regardless of whether they are above the detection limit. The maximum daily concentration for tritium of 1.5 becquerels per milliliter (Bq/mL) was far below the permit discharge limit of 12 Bq/mL (333 picocuries per milliliter [pCi/mL]).

The historical trend in the monthly concentration of tritium is shown in **Figure 5-2** (before 2002, monthly averages were calculated from weekly data). Also shown in the figure are the limit of sensitivity (LOS) values for the tritium analysis and the DOE annualized discharge limit for tritium (370 Bq/mL [0.01 μCi/mL]).

Table 5-3. Cesium and plutonium in LLNL and LWRP sanitary sewer effluents, 2006.[a]

	Cesium-137 (µBq/mL)				Plutonium-239 (nBq/mL)			
	LLNL		LWRP		LLNL		LWRP	
Month	Radioactivity	MDC	Radioactivity	MDC	Radioactivity	MDC	Radioactivity	MDC
Jan	4.40 ± 5.8	5.2	0.97 ± 5.1	4.6	20.9 ± 7.1	9.8	–0.60 ± 3.7	8.0
Feb	6.48 ± 5.2	4.8	5.81 ± 5.3	4.9	11.0 ± 5.5	6.5	0.94 ± 2.3	3.7
Mar	–0.83 ± 6.0	5.1	5.55 ± 5.2	4.8	20.3 ± 5.1	8.6	4.29 ± 3.9	4.4
Apr	–1.17 ± 5.2	4.6	2.27 ± 5.1	4.6	19.8 ± 5.1	8.5	1.85 ± 3.9	4.3
May	2.02 ± 5.9	5.1	–0.85 ± 4.9	4.4	11.7 ± 4.8	6.3	–0.35 ± 2.1	4.6
Jun	–1.80 ± 8.1	7.0	1.46 ± 5.6	5.0	33.5 ± 9.7	14.9	–0.32 ± 2.0	4.3
Jul	1.23 ± 5.5	4.9	7.14 ± 5.3	4.7	12.1 ± 4.1	6.2	0.09 ± 2.8	5.1
Aug	–1.85 ± 5.7	4.9	–0.91 ± 5.6	4.9	35.3 ±11.3	15.8	0.67 ± 2.6	6.0
Sep	2.60 ± 5.3	4.8	–1.79 ± 5.1	4.4	12.1 ± 7.4	7.6	–0.82 ± 2.0	5.2
Oct	1.21 ± 6.4	5.6	–2.91 ± 5.6	4.8	38.9 ± 7.6	14.9	103 ± 1461[b]	1598[b]
Nov	1.33 ± 4.7	4.2	0.37 ± 5.1	4.6	13.1 ± 4.4	6.5	0.00 ± 2.4	4.7
Dec	–1.42 ± 4.9	4.2	5.81 ± 7.4	6.7	7.2 ± 6.9	6.4	2.25 ± 3.9	5.7
Median	0.19		1.21		16.4		0.38	

Annual LLNL total discharge by radioisotope		
	Cesium-137	Plutonium-239
Bq/y[c]	3.91×10^{5}	7.56×10^{3}
Ci/y[c]	1.06×10^{-5}	2.04×10^{-7}

Fraction of limit [d]		
DOE 5400.5 DCG	1.84×10^{-6}	5.39×10^{-8}

(a) Results in this table are reported as radioactivity (the measured concentration and a ± 2σ counting uncertainty) along with the detection limit or minimum detectable concentration (MDC). A measured concentration exhibiting a 2σ counting uncertainty greater than or equal to the measured concentration is considered a nondetection (see **Chapter 9**).

(b) Due to low tracer recovery this sample has a higher detection limit.

(c) 1 Ci = 3.7×10^{10} Bq

(d) Fraction of limit calculations are based on the annual total discharge for a given isotope and the corresponding concentration-based limit (0.56 and 0.37 Bq/mL for cesium-137 and plutonium-239, respectively) multiplied by the annual volume of Livermore site effluent.

Measured concentrations of cesium-137 and plutonium-239 in the sanitary sewer effluent from LLNL and LWRP are listed in **Table 5-3**, and in LWRP sludge, in **Table 5-4**. Cesium and plutonium results are from monthly composite samples of LLNL and LWRP effluent and from quarterly composites of LWRP sludge. For 2006, the annual total discharges of cesium-137 and plutonium-239 were far below the DOE DCGs. Plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge. The highest plutonium concentration observed in 2006 sludge (see **Table 5-4**) is many times lower than the U.S.

Table 5-4. Radioactivity of cesium and plutonium in LWRP sludge, 2006.[a]

Month	Cesium-137 (mBq/dry g)[b]	Plutonium-239 (mBq/dry g)[b]
Mar	21.3	0.234 ± 0.046
Jun	<2.29	0.359 ± 0.086
Sep	1.19	3.119 ± 0.503
Dec	<0.69	1.084 ± 0.184

(a) Sludge from LWRP digesters is dried before analysis. The resulting data indicate the cesium and plutonium concentration of the sludge prepared by LWRP for disposal at the Vasco Road Landfill in Alameda County.

(b) Results are reported as radioactivity (the measured concentration ± 2σ counting uncertainty). A measured concentration exhibiting a 2σ counting uncertainty greater than or equal to 100% is considered to be a nondetection and is reported with a less than (<) symbol. See **Chapter 9**.

Environmental Protection Agency (EPA) preliminary remediation goal for residential soil (93 mBq/dry grams (dry g) [2.5 pCi/dry g]) and is 0.84% of the remediation goal for industrial or commercial soil (370 mBq/dry g [10 pCi/dry g]).

Figure 5-3 summarizes the plutonium-239 and cesium-137 monitoring data over the past 10 years. The historical levels for plutonium-239 observed since 1996 averaged approximately 1 microbecquerel per milliliter (μBq/mL) (3×10^{-5} pCi/mL). The historical levels are generally 0.0003% of the DOE DCG for plutonium-239. The cyclic nature of the data in **Figure 5-3** suggests a relationship between radionuclide buildup in LLNL sewer lines and subsequent liberation by line cleaning. The highest plutonium and cesium concentrations are still well below DOE DCGs.

LLNL also compares annual discharges with historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 5-5** summarizes the radioactivity in sanitary sewer effluent over the past 10 years. During 2006, a total of 19.9 GBq (0.54 Ci) of tritium was discharged to the sanitary sewer, an amount that is

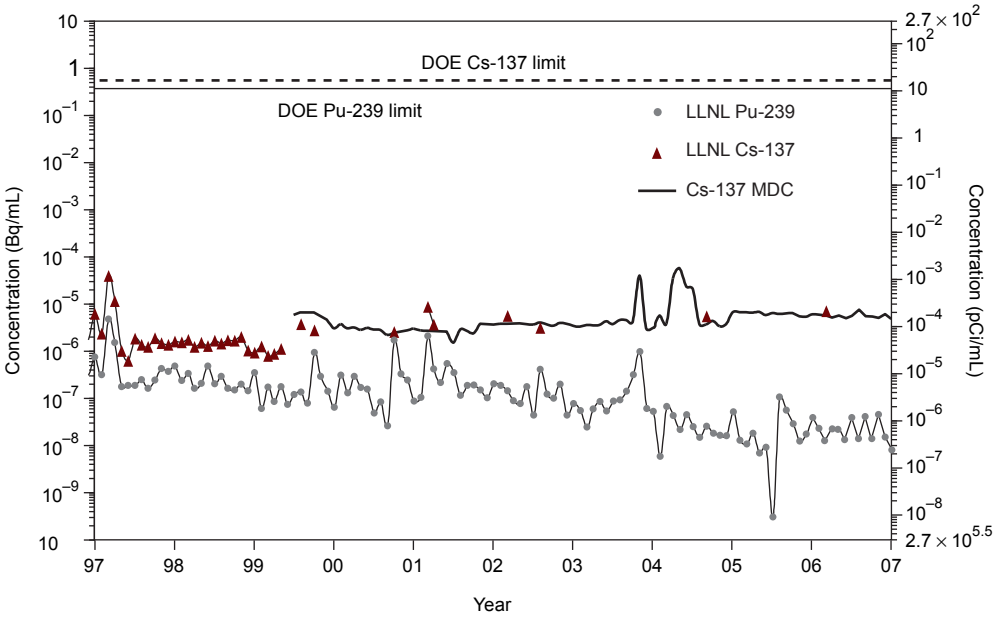

Figure 5-3. Average monthly plutonium-239 (Pu-239) and cesium-137 (Cs-137) concentrations in LLNL sanitary sewer effluent. The DOE annualized discharge limit for application of best available technology is five times the derived concentration guide (DCG: ingested water) for each radionuclide released.

Table 5-5. Historical radioactive liquid effluent releases from the Livermore site, 1996–2006.[a]

Year	Tritium (GBq)	Plutonium-239 (GBq)
1996	12	4.2×10^{-4}
1997	9.1	2.1×10^{-4}
1998	10	0.77×10^{-4}
1999	7.1	0.68×10^{-4}
2000	5.0	0.96×10^{-4}
2001	4.9	1.1×10^{-4}
2002	0.74	0.42×1^{-4}
2003	1.11	0.51×10^{-4}
2004	1.34	1.16×10^{-5}
2005	3.12	9.64×10^{-6}
2006	19.9	7.56×10^{-6}

(a) Starting in 2002, following DOE guidance, actual analytical values instead of LOS values were used to calculate total.

well within environmental protection standards and is comparable to the amounts discharged during the past 20 years.

5.1.1.2 Nonradiological Monitoring Results

LLNL monitors sanitary sewer effluent for chemical and physical parameters at different frequencies depending on the intended use of the result. For example, LLNL's wastewater discharge permit requires LLNL to collect monthly grab samples and 24-hour composites, weekly composites, and daily composites. Once a month, a 24-hour, flow-proportional composite is collected and analyzed; this is referred to as the monthly 24-hour composite in the discussion below. The weekly composite refers to the flow-proportional samples collected over a 7-day period continuously throughout the year. The daily composite refers to the flow-proportional sample collected over a 24-hour period, also collected continuously throughout the year. LLNL's wastewater discharge permit specifies that the effluent pollutant limit (EPL) is equal to the maximum pollutant concentration allowed per 24-hour composite sample. Only when a weekly composite sample concentration is at or above 50% of its EPL are the daily samples that were collected during the corresponding period analyzed to determine whether any of the concentrations are above the EPL.

To better understand the characteristics of the Livermore site sanitary sewer effluent, LLNL also tracks flow-weighted monthly concentrations for all regulated metals in LLNL's sanitary sewer effluent; **Table 5-6** presents the flow-weighted monthly concentrations for 2006. To obtain these concentrations, each weekly composite is weighted by the total flow volume for the period during which the sample was collected. (Daily flow volumes and sample results for the 2006 weekly composites are provided in **Appendix B**, **Section B.3**.) This flow-weighted monthly concentration represents the characteristic concentration for that month. During 2006, the month-to-month characteristic concentrations for each metal closely resemble the 2005 results, showing generally lower concentration values and less variation than the annual trends observed prior to 2005. These results follow from the improved homogeneity of composite effluent samples, made possible by the upgraded sampling system within the SMS that was completed at the end of 2004. In **Table 5-6**, the 2006 median flow-weighted concentration for each metal is shown and compared with the EPL. These median values were less than 5% of their respective EPLs for eight of the nine regulated metals. Only arsenic, with a median value at 7% of its EPL, showed a small increase over 2005.

Figure 5-4 presents historical trends for the monthly 24-hour composite sample results from 2000 through 2006 for eight of the nine regulated metals; cadmium is not presented

Table 5-6. Flow-weighted monthly concentrations for regulated metals in LLNL sanitary sewer effluent (mg/L), 2006.[a]

	Regulated metal								
Month	Silver (Ag)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
Jan	<0.010	0.0032	<0.0050	<0.010	0.039	<0.00020	0.0057	0.0022	0.073
Feb	<0.010	0.0031	<0.0050	<0.010	0.047	<0.00020	<0.0050	0.0022	0.088
Mar	<0.010	0.0040	<0.0050	<0.010	0.041	<0.00020	<0.0050	0.0021	0.082
Apr	<0.010	0.0025	<0.0050	<0.010	0.039	<0.00020	<0.0050	0.0025	0.084
May	<0.010	0.0042	<0.0050	<0.010	0.039	<0.00020	<0.0050	0.0023	0.073
Jun	<0.010	0.0067	<0.0050	<0.010	0.041	0.00022	0.0053	0.0027	0.065
Jul	<0.010	0.0073	<0.0050	<0.010	0.058	<0.00020	<0.0050	0.0047	0.065
Aug	<0.010	0.0071	<0.0050	<0.010	0.053	<0.00020	<0.0050	0.0030	0.074
Sep	<0.010	0.0040	<0.0050	<0.010	0.045	<0.00020	0.0062	0.0022	0.079
Oct	<0.010	0.0032	<0.0050	<0.010	0.041	<0.00033	0.0053	<0.0020	0.074
Nov	<0.010	0.0026	<0.0050	<0.010	0.038	<0.00020	<0.0050	0.0045	0.069
Dec	<0.010	0.0068	<0.0050	<0.010	0.034	<0.00020	<0.0050	0.0021	0.070
Median	<0.010	0.0040	<0.0050	<0.010	0.041	<0.00020	<0.0050	0.0023	0.074
IQR	—[b]	0.0036	—[b]	—[b]	0.006	—[b]	—[b]	0.0006	0.010
EPL[c]	0.20	0.06	0.14	0.62	1.0	0.01	0.61	0.20	3.00
Median fraction of EPL	<0.05	0.07	<0.04	<0.02	0.04	<0.02	<0.01	0.01	0.02
PQL[d]	0.010	0.0020	0.0050	0.010	0.010	0.00020	0.0050	0.0020	0.050

(a) Monthly values are presented with less-than signs when all weekly composite sample results for the month are below the detectable concentration.

(b) Because of the large number of nondetects, the interquartile range cannot be calculated (see **Chapter 9)**.

(c) EPL = Effluent pollutant limit (LLNL Wastewater Discharge Permit 1250, 2005/2006, and 2006/2007.

(d) PQL = Practical quantitation limit (these limits are typical values for sanitary sewer effluent samples).

because this metal was not detected above the practical quantitation limit (PQL) in any of the 2000 through 2006 monthly sampling events. Typical PQLs for the regulated metals in LLNL sanitary effluent are shown in **Table 5-6**. (Sample results for the 2006 monthly 24-hour composites are provided in **Appendix B**, **Section B.3**.) All of the monthly 24-hour composite samples were in compliance with LLNL's wastewater discharge permit limits. The 2006 results routinely show concentrations of arsenic, copper, lead, and zinc at levels above their respective PQLs; nickel was detected in 3 of 12 samples, while silver, chromium, and mercury showed no detections above their respective PQLs. These observations are generally consistent with the 2000 through 2004 data; however, with the exception of arsenic, the concentrations of those metals detected in 2005 and 2006 have shown an overall downward

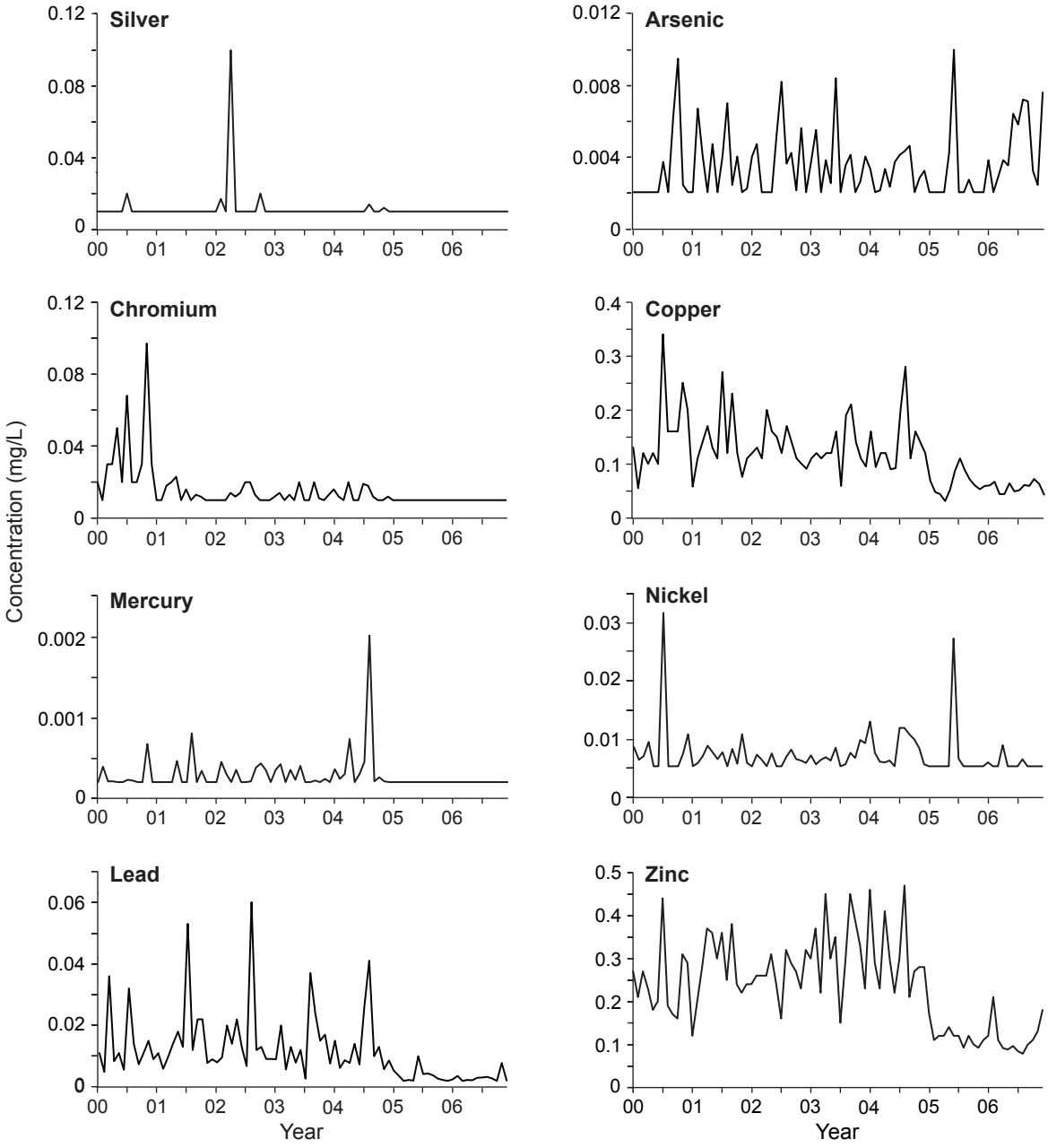

Figure 5-4. Monthly 24-hour composite sample concentrations for eight of the nine regulated metals in LLNL sanitary sewer effluent showing historical trends.

trend. For example, the monthly 24-hour composite concentrations of copper and zinc, which peaked in 2004 at 28% and 16% of their respective EPLs, did not exceed 7.2% and 7%, respectively, of those same EPLs in 2006. The range of monthly 24-hour composite concentrations reported for arsenic in 2006, although never exceeding 13% of its EPL, has not shown a similar downward trend.

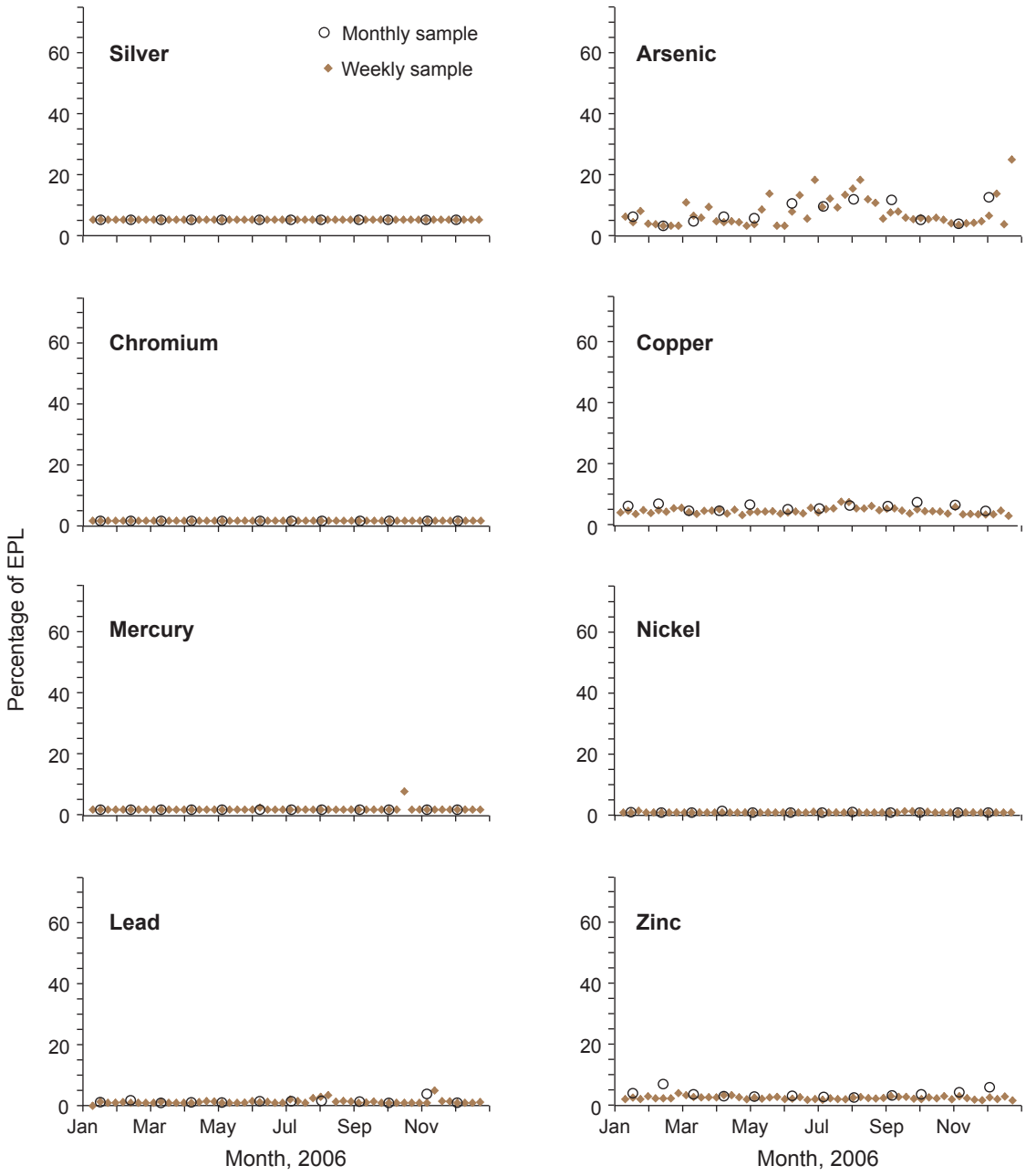

Figure 5-5. The results shown in **Figure 5-4** are shown here as percentages of effluent pollutant limits (EPLs) for eight of the nine regulated metals in LLNL sanitary sewer effluent, 2006.

The monthly 24-hour composite and weekly composite concentrations for 2006 are presented in **Figure 5-5** for eight of nine regulated metals as a percentage of the corresponding EPL. As in past years, cadmium results are not presented because the metal was not detected above the PQL in any of the weekly or monthly samples. In 2006, an additional two (silver and chromium) of the nine regulated metals were not detected above

PQLs in any of the weekly or monthly samples; these results are presented, however, to facilitate comparisons with previous LLNL environmental reports. As discussed above, all of the regulated metal concentrations in the monthly 24-hour composite samples are well below their respective EPLs. Similarly, none of the weekly composite samples showed metal concentrations above 50% of their respective EPLs, and analysis of daily samples was therefore not required. The highest percentage of EPL reported during 2006 was for arsenic (at 25% of EPL) in the December 21–27 weekly composite. All other reported metal concentrations were <20% of the respective EPLs, with most being <10%.

Detections of anions, metals, and organic compounds and summary data concerning other physical and chemical characteristics of the sanitary sewer effluent are provided in **Table 5-7**. (**Table 5-7** does not include the monthly metals results, which are plotted in **Figure 5-5**, or monthly monitoring results for analytes not detected in any of the 24-hour composite or grab samples. All analytical results are provided in **Appendix B**, **Section B.3**.) The 2006 results are similar to typical values seen in previous years for the two regulated parameters, cyanide and total toxic organics (TTO) (see chemicals with a "d" superscript in **Table 5-7**), and all other nonregulated parameters. Cyanide (permit limit 0.04 milligrams per liter [mg/L], sampled semiannually) was below the analytical detection limit (0.02 mg/L) in both the April and October samples. The monthly TTO values ranged from 0.013 mg/L to <0.050 mg/L (with a TTO median value of 0.021 mg/L), well below the TTO permit limit of 1.0 mg/L. In addition to the organic compounds regulated under the TTO standard, three nonregulated organics were detected in LLNL's sanitary sewer effluent: one volatile organic compound (acetone) and two semivolatile organic compounds (benzyl alcohol, and 3- and 4-methylphenol [m- and p-Cresol]).

In 2006, the SMS continuous monitoring system detected a total of six inadvertent discharges outside the permitted pH range of 5 to 10. Five of these events, three with a pH below 5 and two with a pH above 10, were completely captured by the SDF. The remaining event occurred off-hours (Wednesday, April 12, 2006, 10:26 p.m.) when the upstream pHMS was off-line. As a result, a small quantity of sanitary effluent outside the permitted pH range was released to the LWRP system before a diversion to the SDF could be initiated. Approximately 757 L (200 gal) of pH 10.0 to 10.5 effluent were released to the LWRP and another 7571 L (2000 gal) captured. The highest pH recorded during the diversion was 11.75. The LWRP was notified immediately of the low-volume, high pH discharge, but the incident did not represent a threat to the integrity of LWRP operations.

5.1.2 Categorical Processes

The EPA has established pretreatment standards for categories of industrial processes that EPA has determined are major contributors to point-source water pollution. These federal standards include numerical limits for the discharge of industry-specific pollutants. At

Table 5-7. Monthly monitoring summary for physical and chemical characteristics of the LLNL sanitary sewer effluent, 2006.[a]

Sample	Parameter	Detection frequency[b]	Minimum	Maximum	Median	Interquartile range
24-hour composite	**Alkalinity (mg/L)**					
	Bicarbonate alkalinity (as $CaCO_3$)	12 of 12	210	260	235	15.0
	Carbonate alkalinity (as $CaCO_3$)	3 of 12	<2.5	34	<5	—[c]
	Total alkalinity (as $CaCO_3$)	12 of 12	210	270	240	20.0
	Anions (mg/L)					
	Bromide	8 of 12	<0.1	1.5	<0.4	1.5
	Chloride	12 of 12	42	71	56	18
	Fluoride	8 of 12	<0.05	0.22	0.094	—[c]
	Orthophosphate	12 of 12	13	18	16	2.0
	Sulfate	12 of 12	10	18	13	3.0
	Nutrients (mg/L)					
	Ammonia nitrogen (as N)	12 of 12	40	57	52	6.8
	Total Kjeldahl nitrogen	12 of 12	42	92	67	20
	Total phosphorus (as P)	12 of 12	5.3	12	7.2	1.8
	Oxygen demand (mg/L)					
	Biochemical oxygen demand	12 of 12	82	120	100	14.8
	Chemical oxygen demand	12 of 12	200	650	225	25.0
	Solids (mg/L)					
	Settleable solids	3 of 12	<0.1	<0.5	<0.1	—[c]
	Total dissolved solids	12 of 12	180	390	245	27.5
	Total suspended solids	12 of 12	42	170	67	17.2
	Volatile solids	12 of 12	64	190	130	42.5
	Total metals (mg/L)					
	Aluminum	12 of 12	0.092	0.84	0.16	0.11
	Calcium	12 of 12	9.8	18	12	2.2
	Iron	12 of 12	0.41	1.3	0.53	0.18
	Magnesium	12 of 12	2.1	3.8	2.4	0.32
	Potassium	12 of 12	15	26	20	1.5
	Selenium	2 of 12	<0.002	0.0024	<0.002	—[c]
	Sodium	12 of 12	33	50	39	5.0
	Total organic carbon (mg/L)	11 of 12	<10	53	27	11
Grab sample	**Semivolatile organic compounds (µg/L)**					
	Benzyl alcohol	2 of 12	<10	<100	<10	—[c]
	Bis(2-ethylhexyl)phthalate[d]	6 of 12	<5	<50	<5.8	—[c]
	Diethylphthalate[d]	9 of 12	<5	<50	<16	—[c]
	Phenol[d]	5 of 12	<5	<50	<5	—[c]
	m- and p-Cresol	6 of 12	<5	<50	<7.4	—[c]
	Total oil and grease (mg/L)[e]	6 of 8	<5	23	15.5	11.2

Table 5-7 (cont.). Monthly monitoring summary for physical and chemical characteristics of the LLNL sanitary sewer effluent, 2006.[a]

Sample	Parameter	Detection frequency[b]	Minimum	Maximum	Median	Interquartile range
Grab sample (cont.)	**Volatile organic compounds (µg/L)**					
	Acetone	12 of 12	200	580	440	180
	Bromodichloromethane[d]	2 of 12	<1	<1	<1	—[c]
	Chloroform[d]	12 of 12	5.2	18	9.2	6.4
	Methylene chloride[d]	2 of 12	<1	1.3	<1	—[c]
	Toluene[d]	2 of 12	<1	3.3	<1	—[c]
	Trichloroethene[d]	1 of 12	<0.5	1.1	<0.5	—[c]

(a) The monthly sample results plotted in **Figure 5-5** and nondetected analytes are not included in this table.

(b) The number of times an analyte was positively identified, followed by the number of samples that were analyzed (generally 12, one sample for each month of the year).

(c) When the detection frequency is less than or equal to 50%, or there is no range, or there are fewer than six results for a sample parameter, the interquartile range is omitted.

(d) Priority toxic pollutant parameter used in assessing compliance with the total toxic organic (TTO) permit limit of 1 mg/L (1000 µg/L), LLNL Wastewater Discharge Permit 1250, 2005/2006, and 2006/2007.

(e) The requirement to sample for oil and grease has been suspended until further notice per LWRP letter of April 1, 1999; nevertheless, LLNL collects these samples (four per day) semiannually as part of the source control program.

LLNL, the categorical pretreatment standards are incorporated into the wastewater discharge permit (Permit 1250, 2005/2006 and 2006/2007), which is administered by the LWRP.

The processes at LLNL that fall under the standards may change as programmatic requirements dictate. During 2006, the LWRP identified 15 wastewater-generating processes at LLNL that fell under either 40 CFR Part 469, Electrical and Electronic Components Point Source Category, or 40 CFR Part 433, Metal Finishing Point Source Category.

Only processes that discharge to the sanitary sewer require semiannual sampling, inspection, and reporting. Three of the 15 processes discharge wastewater to the sanitary sewer: (1) semiconductor processes (e.g., wafer cleaning/etching, photolithography) in the Building 153 microfabrication facility, (2) gallium arsenide saw cutting in Building 153, and (3) abrasive jet machining in Building 321C. In 2006, LLNL analyzed compliance samples for all regulated parameters from the three discharging processes and demonstrated compliance with all federal categorical discharge limits. Of the three processes, the Building 153 microfabrication facility released the largest volume of water to the sanitary sewer. The wastewater is retained in tanks and then discharged to the sanitary sewer. As a further environmental safeguard, LLNL sampled the wastewater in the each tank prior to discharge to the sanitary sewer. These monitoring data were reported to the LWRP in July 2006 and January 2007 semiannual wastewater reports (Grayson et al. 2006, 2007).

The remaining 12 processes, which do not discharge wastewater to the sanitary sewer, are regulated under 40 CFR Part 433, Metal Finishing; wastewater from these processes is evaluated semiannually. The processes include printed circuit board manufacturing,

electrolysis plating, chemical etching, electroplating, anodizing, coating, electrical discharge machining, and abrasive jet machining. Wastewater from these processes is recycled or contained for eventual removal and appropriate disposal by RHWM. Because the processes do not discharge directly or indirectly to the sanitary sewer, they are not subject to the monitoring and reporting requirements contained in the applicable standard. See Grayson et al. (2006, 2007).

As required in LLNL's wastewater discharge permit, LLNL demonstrated compliance with permit requirements by semiannual sampling and reporting in 2006. In addition, LWRP source control staff performed their required annual inspection and sampling of the three discharging categorical processes in 2006. The compliance samples were analyzed for all regulated parameters, and the results demonstrated compliance with all federal and local pretreatment limits.

5.1.3 Discharges of Treated Groundwater

LLNL's groundwater discharge permit (1510G, 2004-2006) allows treated groundwater from the Livermore site Ground Water Project (GWP) to be discharged in the City of Livermore sanitary sewer system (see **Chapter 8** for more information on the GWP). During 2006, there were seven discharges to the sanitary sewer from the GWP. The total volume of treated groundwater discharged to the sanitary sewer was 5680 L (1501 gal). In each of the discharge events, the groundwater released to the sanitary sewer originated from the lower zone, beneath the LLNL site. These volumes of groundwater were acquired at on-site wells in conjunction with GWP drilling and treatment operations. The seven events were separately sampled and discharged to the sanitary sewer during 2006, all in compliance with self-monitoring permit provisions and discharge limits of the permit. Complete monitoring data are presented in Revelli (2007a).

5.1.4 Environmental Impact of Sanitary Sewer Effluent

During 2006, no discharges exceeded any discharge limits for release of radioactive materials to the sanitary sewer. The data are comparable to the lowest historical values. All the values reported for radiological releases are a fraction of their corresponding limits. For nonradiological releases, LLNL achieved excellent compliance with the provisions of its wastewater discharge permit; there was one release with a pH outside permissible limits.

The data demonstrate that LLNL continues to have good control of radiological and nonradiological discharges to the sanitary sewer. Monitoring results for 2006 reflect an effective year for LLNL's wastewater discharge control program and indicate no adverse impact to the LWRP or the environment from LLNL sanitary sewer discharges.

5.2 Site 300 Sewage Ponds

Wastewater samples collected from the influent to the sewage evaporation pond, within the sewage evaporation pond, and flow to the sewage percolation pond were obtained in accordance with the written, standardized procedures summarized in Woods (2005).

5.2.1 Sewage Evaporation and Percolation Ponds

Sewage generated at buildings in the General Services Area at Site 300 is discharged into a lined evaporation pond. The nonhazardous wastewater is disposed of through evaporation from the pond. However, during winter rains, treated wastewater may discharge into an unlined percolation pond where it enters the ground and the shallow groundwater.

The environmental monitoring requirements for the sewage evaporation and percolation ponds (hereafter collectively referred to as sewage ponds) are specified in the Monitoring and Reporting Program (MRP) for Waste Discharge Requirements Order No. 96-248 (WDR 96-248). The monitoring requirements include both wastewater monitoring and groundwater monitoring to detect potential impacts of the sewage on groundwater quality. Wastewater is sampled quarterly at a sampling point (ISWP) in the pipe running into the sewage pond and within the sewage evaporation pond (ESWP). (Sampling locations are shown in **Figure 5-6**.) Discharges into the adjacent percolation pond are also permitted under WDR 96-248 and are sampled as needed in the discharge pipe (DSWP) from the sewage pond to the percolation pond.

Nine groundwater monitoring wells are sampled semiannually to provide information on the groundwater quality in the vicinity of the sewage ponds. The wells are screened in three geological formations: Qal, $Tnbs_1$, and $Tnsc_1$ (see **Chapter 8)**. The $Tnbs_1$ (Neroly Formation lower blue sandstone unit) is the regional aquifer.

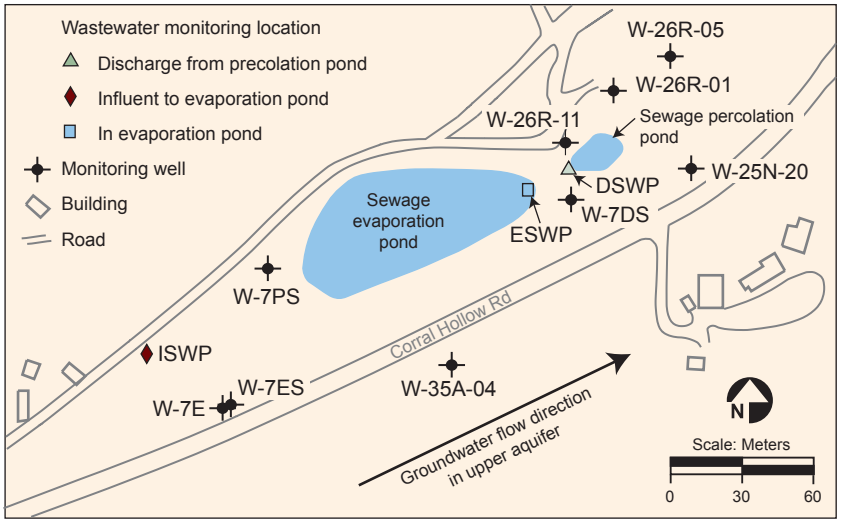

Figure 5-6. Site 300 sewage evaporation and percolation ponds, compliance groundwater monitoring wells, and wastewater monitoring locations, 2006.

All wastewater parameters for the sewage evaporation and percolation ponds complied with permit provisions and specifications throughout 2006. There was one continuous discharge from the sewage evaporation pond to the percolation pond that began in January 2006 and continued for about six weeks. This permitted discharge was sampled once in January and reported to the Central Valley Regional Water Quality Control Board (CVRWQCB). For details, see Brown (2007).

5.2.2 Environmental Impact of Sewage Ponds

All discharges from the Site 300 sewage evaporation pond to the percolation pond were in compliance with discharge limits. Groundwater monitoring related to this area indicated there were no measurable impacts to the groundwater from the sewage pond operations (Brown 2007).

5.3 Storm Water Compliance and Surveillance Monitoring

To assess compliance with permit requirements, LLNL monitors storm water at the Livermore site in accordance with WDR 95-174, National Pollutant Discharge Elimination System (NPDES) Permit No. CA0030023, issued in 1995 by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB 1995a). LLNL monitors storm water discharges at Site 300 in accordance with the California NPDES General Permit for Storm Water Discharges Associated with Industrial Activities (WDR 97-03-DWQ), NPDES Permit No. CAS000001, State Water Resources Control Board (SWRCB 1997). For construction projects that disturb 0.4 hectares (ha) (1 acre [ac]) of land or more, LLNL also meets storm water compliance monitoring requirements of the California NPDES General Permit for Storm Water Discharges Associated with Construction Activity (WDR 99-08-DWQ, NPDES Permit No. CAS000002) (SWRCB 1999) and subsequent modifications.

Site 300 storm water monitoring also meets the requirements of the *Post-Closure Plan for the Pit 6 Landfill Operable Unit* (Ferry et al. 1998). In addition to the storm water quality constituents required by the closure plan, LLNL monitors other constituents to provide a more complete water quality profile. **Appendix C** includes the current list of analyses conducted on storm water, including analytical methods and typical reporting limits.

Storm water monitoring at both sites also follows the requirements in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991) and meets the applicable requirements of DOE Order 5400.5, Radiation Protection of the Public and the Environment.

At all monitoring locations at both the Livermore site and Site 300, grab samples are collected from the storm water runoff flowing in the storm drains and stream channels. Grab samples are collected by partially submerging sample bottles directly into the water and allowing them to fill with the sample water. If the water to be sampled is not directly

accessible, an automatic water sampler is used to pump water into the appropriate containers. Sampling is conducted away from the edge of the arroyo to prevent the collection of sediment into the water samples.

For the purpose of evaluating the overall impact of the Livermore site and Site 300 operations on storm water quality, storm water samples are collected at upstream and downstream locations. Because of flow patterns at the Livermore site, storm water at sampling locations includes runoff from other sources, such as neighboring agricultural land, parking lots, and landscaped areas. In contrast, storm water at Site 300 is sampled at locations that target specific on-site activities with no run-on from off-site sources. These samples provide the information necessary to maintain compliance with the SWRCB permits.

NPDES permits for storm water require that LLNL sample locations specified in the permit two times per rainy season. Influent sampling is also required at the Livermore site. In addition, LLNL is required to visually inspect the storm drainage system during one storm event per month in the wet season (defined as October through April for the Livermore site and October through May for Site 300) to observe runoff quality and twice during the dry season to identify any dry weather flows. Annual facility inspections are also required to ensure that the best management practices for controlling storm water pollution are implemented and adequate.

5.3.1 LLNL Site-Specific Storm Water Thresholds

To maintain compliance with permits and as directed by the LLNL industrial storm water programs, samples from a minimum of two storms per year are collected at both LLNL sites. Various laboratory analyses are performed on the samples collected for each storm. There are no numeric concentration limits for constituents in LLNL's storm water effluent. The EPA has established benchmark concentration values but stresses that the benchmarks are not intended to be interpreted as limits (EPA 2000). The EPA uses the values to determine whether storm water discharged from a facility merits further monitoring. Although the benchmark values are not directly applicable, they are compared to LLNL storm water data to help LLNL evaluate its storm water management program.

To further evaluate the program, LLNL has established site-specific thresholds for selected parameters (Campbell and Mathews 2006). A value exceeds a parameter's threshold when it is greater than the 95% confidence limit for the historical mean value for that parameter (see **Table 5-8**). The thresholds are used to identify out-of-the-ordinary data that merit further investigation to determine whether concentrations of that parameter are increasing in the storm water runoff. These site-specific thresholds are recalculated and changed as additional data become available. For example, in 2006, the copper value was changed to 36 μg/L; see Campbell and Mathews (2006) for details of the calculation. For a better understanding of how LLNL storm water data relate to other target values, LLNL also

Table 5-8. Site-specific thresholds for selected water quality parameters for storm water runoff.[a]

Parameter	Livermore site	Site 300
Total suspended solids	750 mg/L[b]	1,700 mg/L[b]
Chemical oxygen demand	200 mg/L[b]	200 mg/L[b]
pH	<6.0, >8.5[b]	<6.0, >9.0[c]
Nitrate (as NO_3)	10 mg/L[b]	Not monitored
Orthophosphate	2.5 mg/L[b]	Not monitored
Beryllium	1.6 µg/L[b]	1.6 µg/L[b]
Chromium(VI)	15 µg/L[b]	Not monitored
Copper	36 µg/L[b]	Not monitored
Lead	15 µg/L[d]	30 µg/L[b]
Zinc	350 µg/L[b]	Not monitored
Mercury	above RL[e]	1 µg/L[b]
Diuron	14 µg/L[b]	Not monitored
Oil and grease	9 mg/L[b]	9 mg/L[b]
Tritium	36 Bq/L[b]	3.17 Bq/L[b]
Gross alpha radioactivity	0.34 Bq/L[b]	0.90 Bq/L[b]
Gross beta radioactivity	0.48 Bq/L[b]	1.73 Bq/L[b]

(a) If data exceed a site-specific threshold, an investigation is initiated to assess whether data are indicative of a water quality problem.

(b) Site-specific value calculated from historical data and studies. These values are lower than the MCLs and EPA benchmarks except for copper, chemical oxygen demand (COD), total suspended solids (TSS), and zinc.

(c) EPA benchmark.

(d) California and EPA drinking water action level.

(e) RL (reporting limit) = 0.0002 mg/L for mercury.

compares water samples with criteria listed in the *Water Quality Control Plan, San Francisco Bay Basin* (SFBRWQCB 1995b), *The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region, Sacramento and San Joaquin River Basins* (CVRWQCB 1998b), state and federal maximum contaminant levels (MCLs), EPA ambient water quality criteria (AWQC), and EPA benchmark values. However, the greatest importance is placed on the site-specific thresholds calculated from historical concentrations in storm water runoff.

5.3.2 Storm Water Inspections

Each directorate at LLNL conducts an annual inspection of its facilities to verify implementation of the storm water pollution prevention plans (SWPPPs) and to ensure that measures to reduce pollutant discharges to storm water runoff are adequate. LLNL's associate directors certified in 2006 that their facilities complied with the provisions of LLNL's SWPPPs. LLNL submits annual storm water monitoring reports to the SFBRWQCB (Campbell and Brunckhorst 2006) and to the CVRWQCB (Brown 2006) with the results of sampling, observations, and inspections.

For each construction project permitted by WDR 99-08-DWQ, LLNL conducts visual monitoring of construction sites before, during, and after storms to assess the effectiveness of the best management practices. Annual compliance certifications summarize the inspections. Annual compliance certifications for 2006 covered the period of June 2005 through May 2006. When requested by a regional water quality control board, LLNL completes annual compliance status reports covering the same reporting period. During the 2005/2006 reporting period, LLNL had active permits for six projects at the Livermore site and two at Site 300 (see **Chapter 2**, **Table 2-3**). LLNL terminated the permits for two projects at the Livermore site in 2006—the Building 583 Project and the Arroyo Seco Management Plan (work was completed in 2005 but termination documentation was submitted in early 2006).

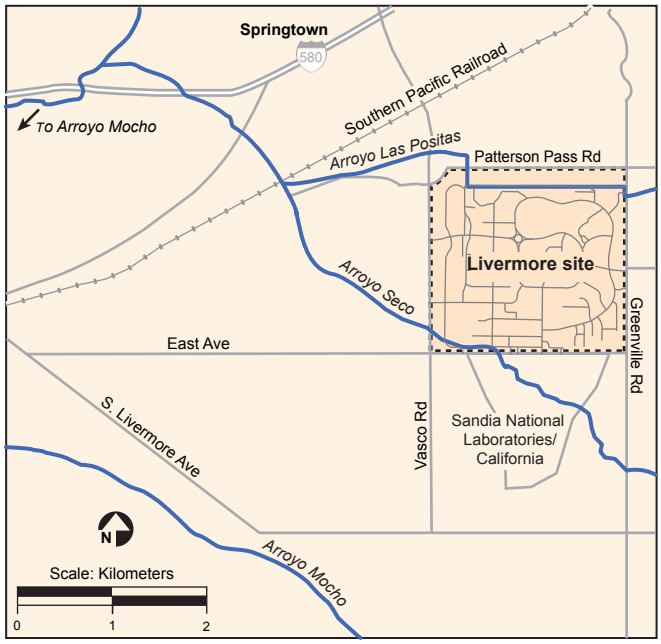

Figure 5-7. Surface waterways in the vicinity of the Livermore site.

5.3.3 Livermore Site

As is common in urban areas, surface water bodies and runoff pathways at LLNL do not represent natural conditions. The drainage at the Livermore site was altered by construction activities several times up to 1966 (Thorpe et al. 1990) so that the current northwest flow of Arroyo Seco and the westward flow of Arroyo Las Positas do not represent historical flow paths. About 1.6 kilometers (km) west of the Livermore site, Arroyo Seco merges with Arroyo Las Positas, which continues to the west and eventually merges with Arroyo Mocho (see **Figure 5-7**).

Lake Haussmann, known prior to 2006 as the Drainage Retention Basin (DRB), was excavated and lined in 1992. Lake Haussmann was constructed and is operated as part of LLNL's Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remediation activities. Although the lake is not a "treatment unit," as the term is used in restoration, the lake was lined to prevent the displacement and dispersion of aquifer contamination actively being treated by the LLNL Environmental Restoration Division. In addition, the lake provides a "polishing" effect on the quality of storm water flowing on to the Livermore site. Lake Haussmann has been determined not to be a "water of the US" (Rauhut 2006) and is therefore managed as such. The lake also serves storm water diversion and flood control purposes, collecting less than one fourth of the surface water runoff from the site and a portion of the Arroyo Las Positas drainage (see **Figure 5-8**). When full, Lake Haussmann discharges north to a culvert that leads to Arroyo Las Positas. The remainder of the Livermore site drains directly or indirectly into the two arroyos by way of storm drains and swales. Arroyo Seco cuts across the southwest corner of the site, and Arroyo Las Positas follows the northeast and north boundaries of the site and exits near the northwest corner.

The Livermore site storm water runoff monitoring network consists of nine sampling locations (see **Figure 5-8**). Six locations characterize storm water either entering (influent: ALPE, ALPO, ASS2, and GRNE) or exiting (effluent: ASW and WPDC) the Livermore site. Sampling locations CDB and CDBW are internal sites used by LLNL outside the requirements of the storm water permit to characterize storm water runoff quality entering Lake Haussmann; location CDBX characterizes water leaving Lake Haussmann. LLNL collected samples at all nine locations on January 18, March 3, and December 12, 2006.

Toxicity tests for WDR 95-174 were performed using water samples from the first major runoff event of the water year occurring during normal work hours (Monday through Friday,

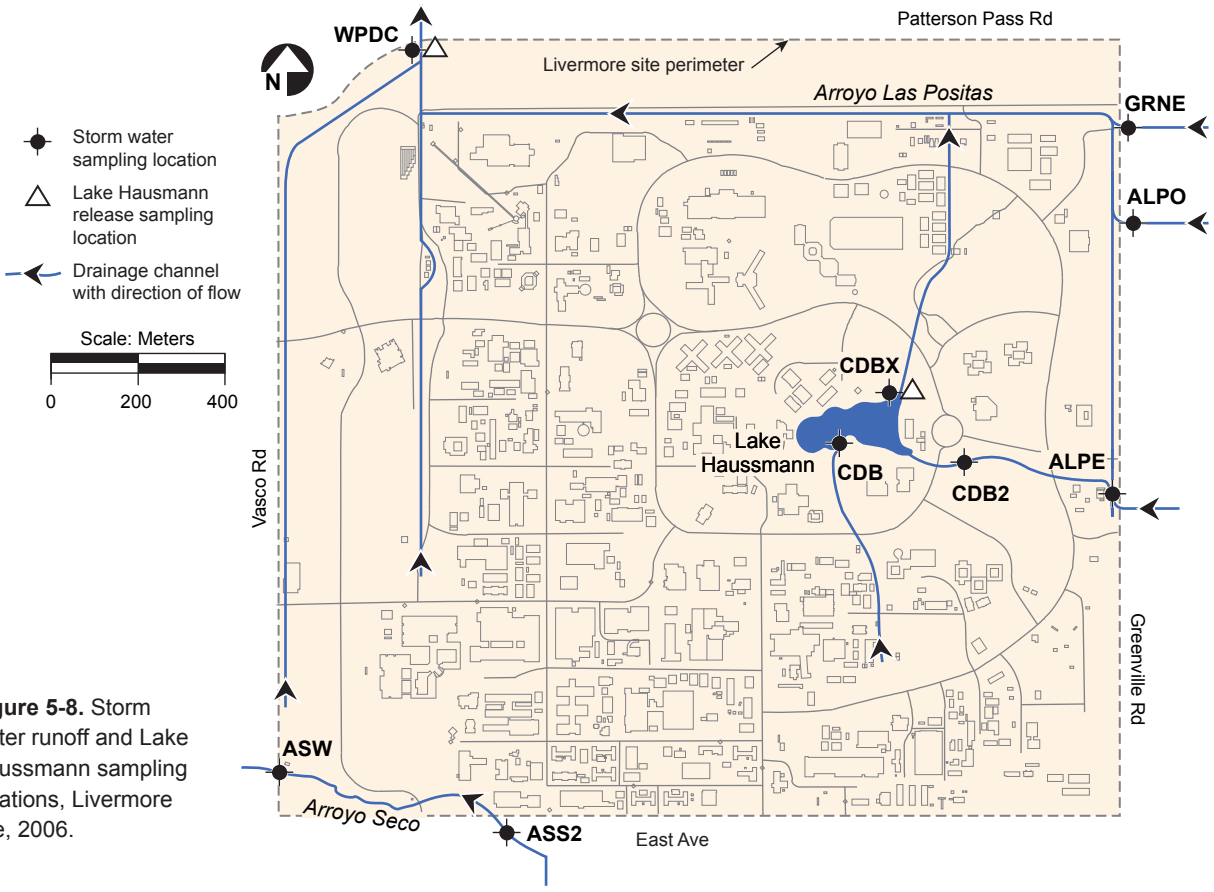

Figure 5-8. Storm water runoff and Lake Haussmann sampling locations, Livermore site, 2006.

Table 5-9. Radioactivity in storm water from the Livermore site, 2006.[(a)]

Parameter	Tritium (Bq/L)	Gross Alpha (Bq/L)	Gross Beta (Bq/L)
MCL	740	0.555	1.85
Influent			
Median	0.28	0.052	0.235
Minimum	–3.40	0.016	0.067
Maximum	5.40	0.290	0.740
Effluent			
Median	1.14	0.032	0.135
Minimum	–1.50	–0.012	0.091
Maximum	4.10	0.046	0.170

(a) See **Chapter 9** for an explanation of calculated values.

8 a.m. to 5 p.m.). Because the first major storms for both 2005–2006 and 2006–2007 water years occurred during calendar year 2006 (sample dates: January 18 and December 12, 2006), they are reported in this document.

5.3.3.1 Radiological Monitoring Results

Storm water sampling and analysis were performed for gross alpha, gross beta, plutonium, and tritium. Storm water gross alpha, gross beta, and tritium results are summarized in **Table 5-9**. (Complete analytical results are provided in **Appendix B**, **Section B.4**.) Tritium activities at the site effluent sampling locations were less than 1% of the MCL. Gross alpha and gross beta radioactivity in the storm water samples collected during 2006 were also generally low, less than 53% and 40% of their MCLs, respectively.

Table 5-10. Water quality parameters in storm water runoff above LLNL site-specific thresholds, Livermore site, 2006.

Nonradioactive/ Radioactive	Parameter	Date	Location	Influent / Effluent	Result	LLNL threshold
Nonradioactive	Chromium(VI) (mg/L)	12/12	GRNE	Influent	0.032	0.015
	Diuron (mg/L)	1/18	ALPO	Influent	0.019	0.014
		1/18	ASW	Effluent	0.037	0.014
		1/18	GRNE	Influent	3.200	0.014
		3/3	GRNE	Influent	0.620	0.014
		3/3	CDB2	Internal	0.016	0.014
		12/12	WPDC	Effluent	0.018	0.014
		12/12	ALPO	Influent	0.620	0.014
	Nitrate (NO_3) (mg/L)	1/18	GRNE	Influent	25.0	10.0
		3/3	ASW	Effluent	31.0	10.0
		3/3	GRNE	Influent	23.0	10.0
		12/12	GRNE	Influent	16.0	10.0
	pH	3/3	CDBX	Internal	8.60	8.50
Radioactive	Gross beta (Bq/L)	3/3	ALPE	Influent	0.74 ± 0.17	0.48

Gross beta activities exceeded LLNL-specific thresholds on March 3, 2006, in water samples collected at influent location ALPE along Arroyo Las Positas. However, gross beta activities in samples collected from the effluent location WPDC were well below the thresholds (see **Table 5-10**). Therefore, this result was unlikely to be related to LLNL activities.

LLNL began analyzing for plutonium in storm water in 1998. Current storm water sampling locations for plutonium are the Arroyo Seco and the Arroyo Las Positas effluent locations (ASW and WPDC). In 2006, there were no plutonium results above the detection limit of 0.0037 Bq/L (0.10 pCi/L).

5.3.3.2 Nonradiological Monitoring Results

In addition to radioactivity, storm water was analyzed for other water quality parameters in 2006. Results were compared to the site-specific thresholds listed in **Table 5-8**. Of interest were the constituents that exceeded the thresholds at effluent points and whose concentrations were lower in influent than in effluent. If influent concentrations are higher than effluent concentrations, the source is generally assumed to be unrelated to LLNL operations and LLNL conducts no further investigation. (Complete analytical results are provided in **Appendix B**, **Section B.4**.)

Constituents that exceeded site-specific thresholds for effluent and/or influent locations are listed in **Table 5-10**. All of the values above the site-specific thresholds for the Livermore site

during 2006 were found at influent tributaries at similar or higher concentrations than at effluent locations, except at location ASW for diuron on January 18 and nitrate on March 3. For example, the diuron concentration at effluent location WPDC is clearly explained by the high value at influent location ALPO (0.620 mg/L) on the same date. Diuron is a pre-emergent pesticide that is used both by LLNL and off site by other parties along roads and structures. The presence of diuron in runoff flowing onto the LLNL site has been documented by Campbell et al. (2004). LLNL pesticide records for January do not indicate that LLNL was using a diuron-containing pesticide in the vicinity of Arroyo Seco (influent location ASS2, 0.019 mg/L; effluent location ASW, 0.037 mg/L). An off-site source for the pesticide is therefore more likely. The elevated nitrate value in March (influent location ASS2, 1.1 mg/L; effluent location ASW, 31.0 mg/L) could have been the result of planting and vegetation management activities associated with a large restoration project in the reach of Arroyo Seco on the Livermore site. LLNL will continue to monitor diuron and nitrates in Arroyo Seco to determine whether these results are isolated.

Two results from storm water samples collected from internal sampling locations around Lake Haussmann contained elevated diuron and pH. The diuron occurred at the influent to the lake and was possibly a small contribution from off site. The pH was from the lake outlet sampling location; elevated pH values for the lake are not unusual (see discussion of Lake Haussmann in **Section 5.5.3**).

The remaining value that exceeded a site-specific threshold originated off site and flowed on site in the Arroyo Las Positas tributaries was the gross beta activity in a sample from location ALPE on March 3. The total suspended solids result was also slightly higher than typical at location ALPE on March 3 (290 mg/L), and because radioactive materials are most often associated with sediments, it is likely that the elevated gross beta activity is the result of the suspended sediments. Other than an elevated diuron result on December 12, the storm water from these upstream influent sampling locations did not significantly influence water quality in Arroyo Las Positas at the effluent sampling location WPDC.

LLNL conducted both 96-hour acute and 7-day chronic fish toxicity analyses on storm water samples collected on January 18 and December 12 from effluent location WPDC. The WDR 95-174 permit states that an acceptable survival rate for the chronic toxicity testing is 20% lower than a control sample. The testing laboratory provides water for the control sample, which consists of EPA synthetic moderately hard water. Thus, a difference of more than 20% between location WPDC and the control sample with the lowest survival rate is considered a failed test. If the test is failed, the permit requires LLNL to conduct toxicity testing during the next significant storm event. After failing two consecutive tests, LLNL must perform a toxicity reduction evaluation to identify the source of the toxicity. During 2006, survival in the 96-hour acute test for a solution of storm water sample from location WPDC was 100% for January 18 and 100% for December 12. The 7-day chronic toxicity tests using the fathead minnows exposed to different concentrations of the storm water also

Table 5-11. Seven-day chronic toxicity test results for fish (fathead minnow) assay from location WPDC, Livermore site, 1/18/06 and12/12/06.

Percent storm water solution	Average percent survival	
	1/18/06	12/12/06
Lab control	95%	100%
12.5%	100%	87.5%
25%	100%	95%
50%	95%	85%
75%	100%	100%
100%	100%	95%

found no significant toxicity (see **Table 5-11**). The results show that LLNL's effluent water sample shows no toxicity, either acute or chronic, to the fathead minnows.

5.3.4 Site 300

Surface water at Site 300 consists of seasonal runoff, springs, and natural and man-made ponds. The primary waterway in the Site 300 area is Corral Hollow Creek, an ephemeral stream that borders the site to the south and southeast. No natural, continuously flowing streams are present in the Site 300 area. Elk Ravine is the major drainage for most of Site 300; it extends from the northwest portion of the site to the east–central area. Elk Ravine drains the center of the site into Corral Hollow Creek, which drains eastward toward the San Joaquin River Basin. Some smaller canyons in the northeast portion of the site drain to the north and east toward Tracy.

Site 300 has at least 23 springs; 19 are perennial and 4 are intermittent. Most of the springs have very low flow rates and are recognized only by small marshy areas, pools of water, or vegetation.

In 2006, storm water runoff was characterized at three sampling locations that could be affected by specific Site 300 industrial activities. In addition, samples from off-site location CARW2 are used to characterize Corral Hollow Creek upstream because the location is unaffected by Site 300 industrial storm water discharges. Samples from off-site location GEOCRK are used to characterize Corral Hollow Creek downstream of Site 300. Sampling locations are shown in **Figure 5-9**.

The Site 300 storm water permit specifies sampling a minimum of two storms per rainy season. Typically, a single storm does not produce runoff at all Site 300 locations because the site receives relatively little rainfall and is largely undeveloped with few paved areas. Therefore, at many locations, a series of large storms is required to saturate the ground before runoff occurs. At some of the sampling locations in some years, there has not been enough rain to generate runoff over an entire rainy season. On January 18 and March 7, 2006, storm water samples were collected and analyzed from all locations that normally have storm water flow.

5.3.4.1 Radiological Monitoring Results

In 2006, storm water sampling and analysis were performed for gross alpha and gross beta radioactivity, uranium isotopes, and tritium, and results were compared with the site-specific thresholds listed in **Table 5-8**. (Complete analytical results are provided in **Appendix B**, **Section B.4**.) Tritium was detected in a storm water sample from location GEOCRK at 3.8 Bq/L (102 pCi/L) (see **Table 5-12**), the first detection of tritium in any storm water

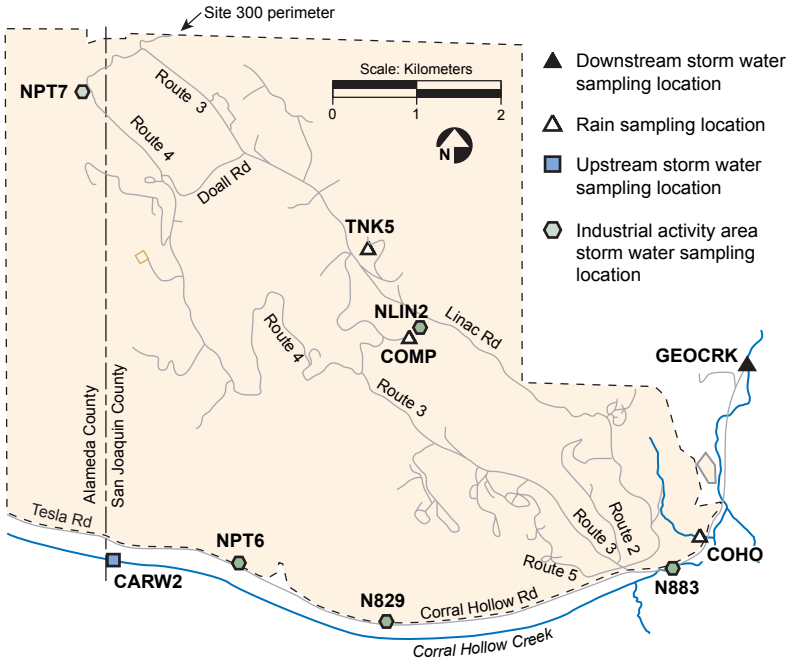

Figure 5-9. Storm water and rainwater sampling locations at Site 300, 2006.

sample collected from Site 300 above the threshold limit. LLNL will continue to track this tritium to see whether any trends develop. No concentrations of gross alpha and gross beta radioactivity in the storm water samples collected from any location exceeded LLNL's site-specific thresholds.

5.3.4.2 Nonradiological Monitoring Results

In 2006, Site 300 storm water samples were analyzed for nonradiological water quality parameters, and sample results were compared with the site-specific thresholds listed in **Table 5-8**. Constituents that exceeded the thresholds for sampled locations are listed in **Table 5-11**.

Table 5-12. Water quality parameters in storm water runoff above LLNL site-specific thresholds, Site 300, 2006.

Radioactive/ nonradioactive	Parameter	Date	Location	Upstream/, downstream/ effluent	Result	LLNL tthreshold
Radioactive	Tritium (Bq/L)	3/7/06	GEOCRK	Downstream	3.8 ± 2.2	3.17
Nonradioactive	Beryllium (mg/L)[(a)]	1/18/06 3/7/06	CARW2 NLIN2	Upstream Effluent	0.0019 0.0022	0.0016 0.0016
	Lead (mg/L)[(a)]	1/18/06	CARW2	Upstream	0.033	0.030
	Chemical oxygen demand (mg/L)	1/18/06	NLIN2	Effluent	300	200

(a) Total metals including particulates.

Concentrations of beryllium and lead collected from upstream location CARW2, and of beryllium collected from effluent location NLIN2 exceeded their respective Site 300 threshold limits.

LLNL staff compared the monitored concentrations to those at the upstream (CARW2) and downstream (GEOCRK) receiving water monitoring locations in both the January and the March events. In the January event, the monitored concentration for beryllium of 0.0019 mg/L at the upstream monitoring location was just above the site-specific threshold of 0.0016 mg/L, and the concentration at the downstream location was below the detection limit. In March, the concentration of beryllium at the upstream monitoring location (CARW2) was just above the detection limit at 0.00021 mg/L, and the value at the downstream monitoring location (GEOCRK) was below the detection limit. Based on this evaluation, LLNL staff concluded that the on-site concentration of beryllium at NLIN2 in the March event was consistent with natural concentrations of this constituent within the measurement limits of error and did not adversely affect downstream runoff. Concentrations of both beryllium and lead in samples collected from upgradient location CARW2 have remained higher than Site 300-specific thresholds through January 2006.

LLNL noted that chemical oxygen demand concentrations (300 mg/L) in a sample collected from effluent location NLIN2 on January 18 exceeded the threshold (200 mg/L). In the autumn 2005, LLNL moved previous monitoring location NLIN upstream nearly 2 km to present location NLIN2 for logistical reasons to avoid delays in sample collection. LLNL staff believe that organic material is being mobilized by runoff from a wetland area immediately upstream of sample location NLIN2. (Complete analytical results are provided in **Appendix B**, **Section B.4.**)

Because of a CERCLA remedial investigation finding of past releases of dioxins and polychlorinated biphenyls (PCBs) related to activities in the vicinity of Building 850, analysis for these compounds was conducted on runoff samples collected from locations CARW2, NLIN2 (sampling location downstream from Building 850), and GEOCRK. The intent of the sampling was to determine whether these constituents are being released down Elk Ravine and eventually off site in storm water runoff. (Complete analytical results are provided in **Appendix B**, **Section B.4**.) No PCBs were detected in those samples. All dioxins detected were below the equivalent federal MCL of 30 picograms per liter (pg/L).

The federal MCL for dioxin and furans (dioxin-like compounds) is for the most toxic congener 2,3,7,8-tetrachloro-dibenzo-*p*-dioxin (2,3,7,8-tetraCDD). The other dioxin and furan congeners have varying degrees of toxicity. EPA has assigned toxicity equivalency factors (TEFs) to specific dioxin and furan congeners. The congeners 2,3,7,8-tetraCDD and 1,2,3,7,8-pentaCDD have an assigned TEF of 1; the other dioxin and furan congeners have TEFs of <1. The toxicity equivalency (TEQ) is determined by multiplying the concentration of a dioxin and furan congener by its TEF. See **Appendix B**, **Section B.4**, for the concentrations of dioxin and furan compounds that have non-zero TEFs along with their calculated TEQs. If the very conservative approach of adding congeners that were not

detected at concentrations equal to one half the analytical reporting limits is used, total TEQs for each location and each sampling event (from 1.2 to 19 pg/L) are all below the federal MCL of 30 pg/L for 2,3,7,8-tetraCDD and are well below the concentrations of similar dioxins and furans measured at locations NLIN (slightly downstream from location NLIN2) and GEOCRK in 2002 (see Sanchez 2003). The highest total TEQ was 19 pg/L for samples collected from location NLIN2 for the March 7 sampling event. LLNL will continue to monitor storm water concentrations to determine whether trends are emerging.

5.3.5 Environmental Impact of Storm Water

Storm water runoff from the Livermore site did not have any apparent environmental impact in 2006. Tritium activities in storm water runoff effluent were <1% of the drinking water MCL. Gross alpha and gross beta activities in effluent samples at the Livermore site were both far less than their respective MCLs. Site 300 storm water monitoring continues to show that most contaminants (including dioxins and furans, lead, and beryllium) are transported sorbed to suspended sediments in the water; however, these concentrations pose no threat to the environment.

5.4 Groundwater

LLNL conducts surveillance monitoring of groundwater in the Livermore Valley and at Site 300 through networks of wells and springs that include off-site private wells and on-site DOE CERCLA wells. The groundwaters that are monitored at the Livermore site and Site 300 are not connected; they are separated by a major drainage divide and numerous faults.

To maintain a comprehensive, cost-effective monitoring program, LLNL determines the number and locations of surveillance wells, the analytes to be monitored, the frequency of sampling, and the analytical methods to be used. A wide range of analytes is monitored to assess the impact, if any, of current LLNL operations on local groundwater resources. Because surveillance monitoring is geared to detecting substances at very low concentrations in groundwater, contamination can be detected before it significantly impacts groundwater resources. Groundwater monitoring wells at the Livermore site, in the Livermore Valley, and at Site 300 are included in LLNL's surveillance monitoring plan.

Historically, the surveillance and compliance monitoring programs have detected higher-than-natural background concentrations of various metals, nitrate, perchlorate, and depleted uranium in groundwater at Site 300. Subsequent CERCLA studies have linked several of these contaminants, including depleted uranium and perchlorate, to past operations, while the source of other contaminants, such as nitrate, is the object of continuing study.

Beginning in January 2003, LLNL implemented a new CERCLA comprehensive compliance monitoring plan at Site 300 (Ferry et al. 2002) that adequately covers the DOE

requirements for on-site groundwater surveillance; LLNL monitoring related to CERCLA activities is described in **Chapter 8**. Additional monitoring programs at Site 300 comply with numerous federal and state controls such as state-issued permits associated with closed landfills containing solid wastes and with continuing discharges of liquid waste to sewage ponds and percolation pits; the latter are discussed in **Section 5.2.3**. Compliance monitoring is specified in WDRs issued by the CVRWQCB and in landfill closure and post-closure monitoring plans. (See **Chapter** 2, **Table 2-2** for a summary of LLNL permits.)

The WDRs and post-closure plans specify wells and effluents to be monitored, constituents of concern (COCs) and parameters, frequency of measurement, inspections, and the frequency and form of required reports. These monitoring programs include quarterly and semiannual monitoring of groundwater, monitoring of various influent waste streams, and visual inspections. LLNL performs the maintenance necessary to ensure the physical integrity of closed facilities, such as those that have undergone CERCLA or RCRA closure, and their monitoring networks.

Typically, because they are both accurate and sensitive, analytical methods approved by EPA are used to measure dissolved constituents in water. **Appendix C** lists the analytical methods and reporting limits that are used to detect organic and inorganic constituents in groundwater (including specific radioisotopes analyzed by alpha spectroscopy and other sensitive methods). The listed methods are not all used for samples from each groundwater monitoring location. Rather, for cost effectiveness, only contaminants that have been detected historically or that might result from continuing LLNL operations are monitored at each groundwater sampling location. However, present-day administrative, engineering, and maintenance controls at both LLNL sites are tailored to prevent releases of potential contaminants to the environment.

During 2006, representative samples of groundwater were obtained from monitoring wells in accordance with the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures* (Goodrich and Wimborough 2006). The procedures cover sampling techniques and information concerning the chemicals that are routinely analyzed for in groundwater. Different sampling techniques were applied to different wells depending on whether they were fitted with submersible pumps or had to be bailed. All of the chemical and radioactivity analyses of groundwater samples were performed by California-certified analytical laboratories. For comparison purposes only, some of the results were compared with drinking water limits (MCLs); however, MCLs do not apply as regulatory limits to any of these groundwaters.

5.4.1 Livermore Site and Environs

5.4.1.1 Livermore Valley

LLNL has monitored tritium in water hydrologically downgradient of the Livermore site since 1988. Tritiated water (HTO) is potentially the most mobile groundwater contaminant

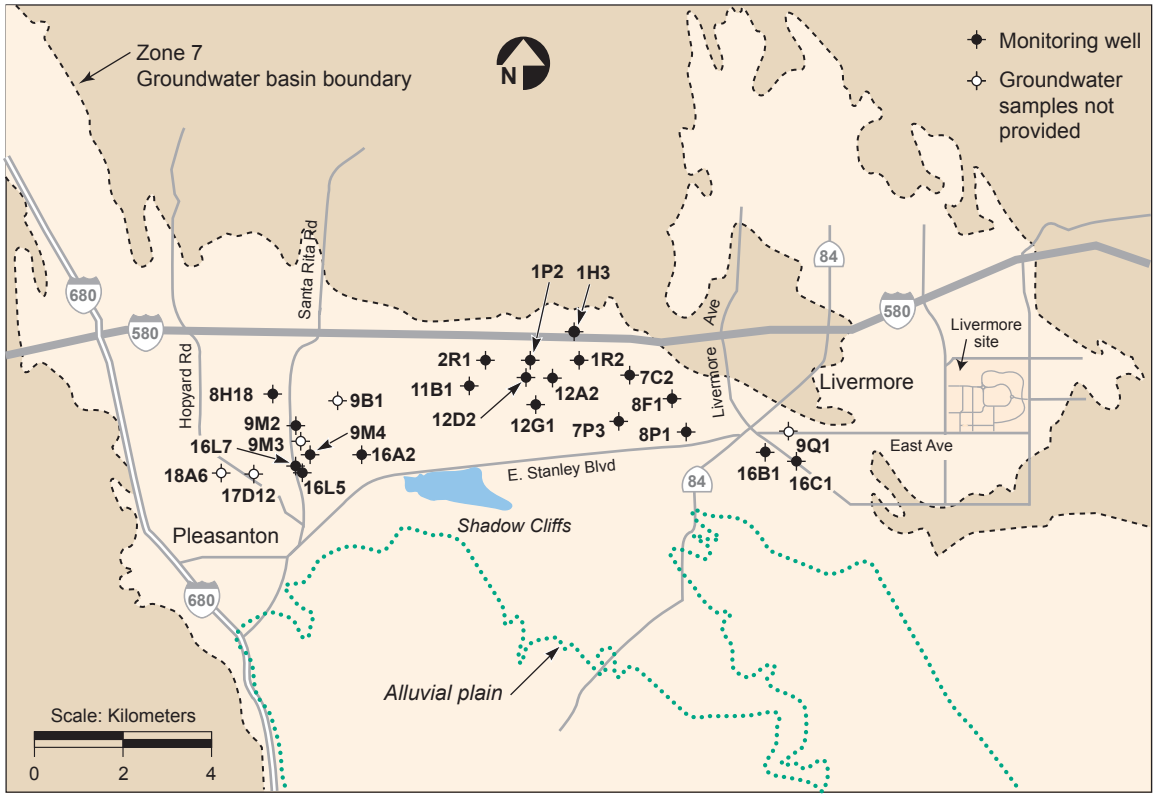

Figure 5-10. Off-site tritium monitoring wells in the Livermore Valley, 2006.

from LLNL operations. Rain and storm water runoff in the Livermore Valley, which recharge local aquifers, contain small amounts of HTO from natural sources, previous worldwide atmospheric nuclear weapons tests, and atmospheric emissions from LLNL. (See **Chapters 4** and **7** for further discussion of air emissions and other parts of this chapter for further discussion of rain and storm water runoff.)

Groundwater is recharged at the Livermore site, primarily from arroyos, by rainfall. Groundwater flow beneath the Livermore site is generally southwestward. An overview of groundwater flow is provided in **Chapter 1** and is discussed in detail in Thorpe et al. (1990) and Karachewski et al. (2007).

Groundwater samples were obtained during 2006 from 20 of 25 water wells in the Livermore Valley (see **Figure 5-10**) and measured for tritium activity. Five wells were either dry or could not be sampled during 2006.

Tritium measurements of Livermore Valley groundwaters are provided in **Appendix B**, **Section B.5**. The measurements continue to show very low and decreasing activities compared with the 740 Bq/L (20,000 pCi/L) MCL established for drinking water in California. The maximum tritium activity measured off site was in the groundwater at

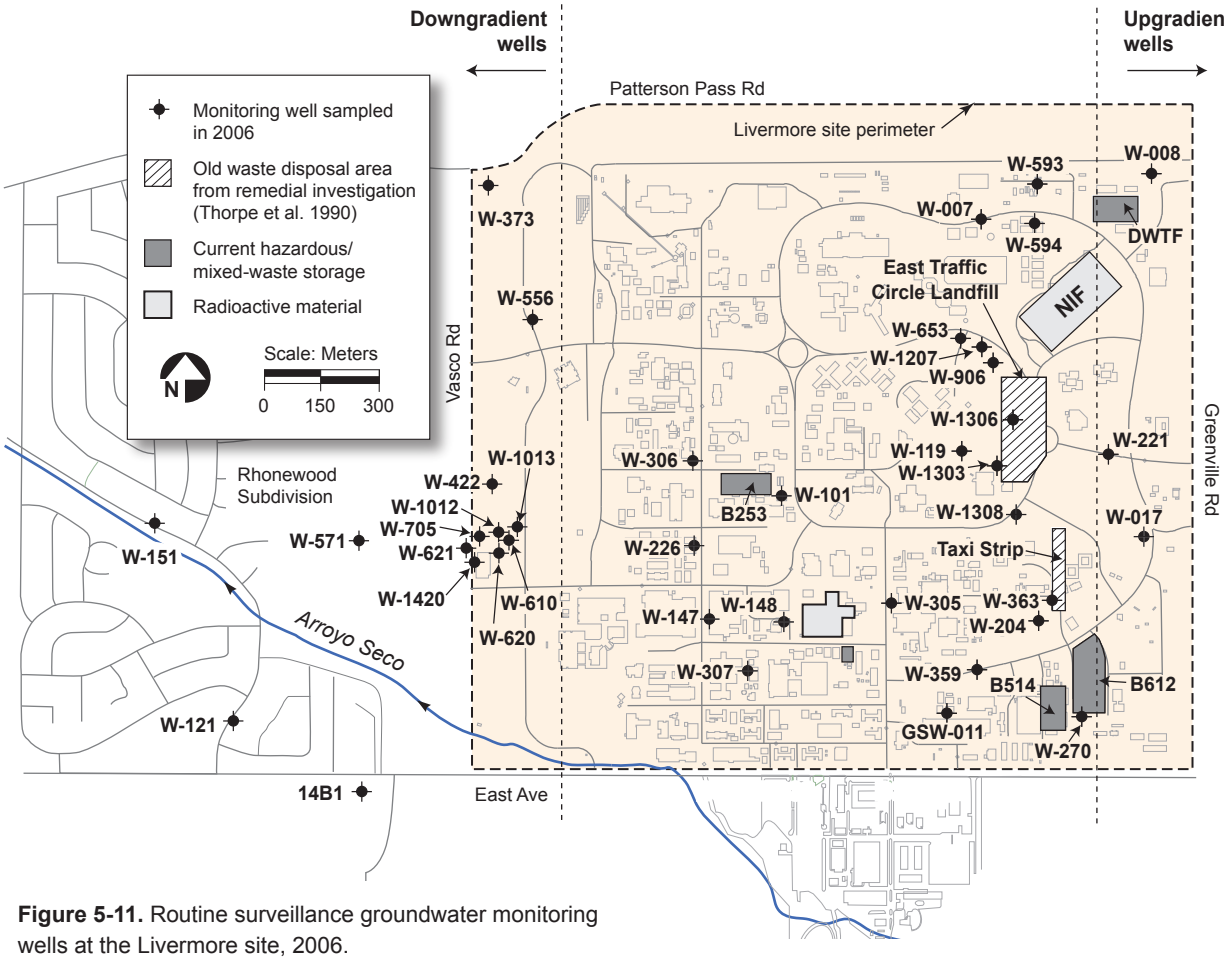

Figure 5-11. Routine surveillance groundwater monitoring wells at the Livermore site, 2006.

well 9M2, located about 14 km west of LLNL (see **Figure 5-10**). The measured activity there was 2.7 Bq/L (72.6 pCi/L) in 2006, less than 0.5% of the MCL.

5.4.1.2 Livermore Site Perimeter

LLNL's groundwater surveillance monitoring program was designed to complement the Livermore Site GWP (discussed in **Chapter 8**). The intent of the program is to monitor for potential groundwater contamination from LLNL operations. The perimeter portion of the surveillance groundwater monitoring network uses three upgradient (background) monitoring wells (wells W-008, W-221, and W-017) near the eastern boundary of the site and seven (downgradient) monitoring wells located near the western boundary (wells 14B1, W-121, W-151, W-1012, W-571, W-556, and W-373) (see **Figure 5-11**). The seven wells, located in the regions of groundwater treatment facilities A, B, and C (TFA, TFB, and TFC) (see **Figure 8-1**), are located at or beyond the hydrologically downgradient boundary of the Livermore site. The western perimeter wells are screened (depth range from which groundwater is drawn) in the uppermost aquifers near the areas where groundwater is being

remediated. As discussed in **Chapter 8**, the alluvial sediments have been divided into nine hydrostratigraphic units (HSUs) dipping gently westward, which are shown in **Figure 8-1**. Screened intervals for these monitoring wells range from the shallow HSU-1B, in which some of the western monitoring wells are screened, to the deeper HSU-5, in which background well W-017 and some wells around Buildings 514 and 612 are screened.

Two of the background wells, W-008 and W-221, are screened partially in HSU-3A; well W-017 is considered a background well for the deeper HSU-5. These background wells were sampled and analyzed in 2006 for pesticide and herbicide compounds that are used on and off site for nitrate, for hexavalent chromium [chromium(VI)], and for certain radioactive constituents including plutonium.

To detect contaminants as quickly as possible, the seven western downgradient wells (except well 14B1) were screened in shallower HSU-1B and HSU-2, the uppermost water-bearing HSUs at the western perimeter. (Because it was originally a production well, well 14B1 was screened over a depth range that includes HSU-2, HSU-3A, and HSU-3B.) These wells were sampled and analyzed at least once during this reporting period for pesticides, herbicides, radioactive constituents, nitrate, and chromium(VI).

Analytical results for the Livermore site perimeter wells are provided in **Appendix B**, **Section B.5**. One sample from the western perimeter (downgradient) well W-121 was reported to contain the pesticide merphos (1.2 micrograms per liter [µg/L]); however, this result is suspect due to analytical quality-control complications reported by the analytical laboratory. An independent retest of this well in January 2007 failed to confirm the detection. No pesticide or herbicide organic compounds were detected above analytical reporting limits in groundwater samples from the other perimeter (upgradient or downgradient) wells during 2006. The inorganic compounds detected include dissolved trace metals and minerals, which occur naturally in the groundwater. Although there have been variations in these concentrations since regular surveillance monitoring began in 1996, the concentrations detected in the 2006 groundwater samples from the upgradient wells represent current background values.

Historically, chromium(VI) has been detected above the MCL (50 µg/L) in groundwater samples from western perimeter well W-373. Since well W-373 was first monitored in 1989, chromium(VI) concentrations have ranged from 160 µg/L (in 1989) to 39 µg/L (in 2005), with an overall downward trend that first dropped below the MCL in 2002. Although the 2006 sample from well W-373 showed a slight increase in the chromium(VI) concentration (52 µg/L), this change is consistent with previous year-to-year variability. An independent retest of this well in January 2007 reported a chromium(VI) concentration of 37 µg/L.

From 1996 through 2004, concentrations of nitrate detected in groundwater samples from downgradient well W-1012 were greater than the MCL of 45 mg/L. The nitrate concentrations detected in samples from this well during 2006 (35 and 32 mg/L) were below the MCL, continuing the downward trend noted in the 2005 (43 and 41 mg/L). The highest concentration measured in the downgradient off-site wells (screened in HSU-1B and HSU-2)

remained below the MCL: 41 mg/L in monitoring well W-151. During 2006, concentrations of nitrate in on-site shallow background wells W-008 and W-221 ranged from 24 mg/L to 32 mg/L. Detected concentrations of nitrate in western perimeter wells ranged from 14 mg/L (in well W-373) to 43 mg/L (in well W-556).

In 2006, nitrate concentrations were also analyzed in groundwater samples collected from seven additional monitoring wells near well W-1012 (see **Figure 5-11**), similarly screened in HSU-1B and HSU-2. Again, no groundwater sample had a nitrate concentration greater than the MCL. Fluctuations in nitrate concentrations have occurred since regular surveillance monitoring began in 1996, but nitrate concentrations have not increased overall in groundwater from the western perimeter monitoring wells since 1996. The nitrate may originate as an agricultural residue (Thorpe et al. 1990).

No concentrations of plutonium radioisotopes were detected above the radiological laboratory's minimum detectable activities in any of the samples from LLNL's site perimeter wells in 2006. Gross alpha, gross beta, radium-226, and tritium were detected occasionally and at levels consistent with the results from recent years; however, the concentrations again remain well below drinking water MCLs.

5.4.1.3 Livermore Site

Groundwater sampling locations within the Livermore site include areas where releases to the ground may have occurred in the recent past, where previously detected COCs have low concentrations that do not require CERCLA remedial action, and where baseline information needs to be gathered for the area near a new facility or operation. Wells selected for monitoring are screened in the uppermost aquifers and are downgradient from and as near as possible to the potential release locations. Well locations are shown in **Figure 5-11**. All analytical results are provided in **Appendix B**, **Section B.5**.

The Taxi Strip and East Traffic Circle Landfill areas within the Livermore site (see **Figure 5-11**) are two potential sources of historical groundwater contamination. Samples from monitoring wells screened in HSU-2 (W-204) and HSU-3A (W-363) downgradient from the Taxi Strip Area were analyzed in 2006 for copper, lead, zinc, americium-241, plutonium-238, plutonium-239, radium-226, radium-228, and tritium. Samples from monitoring wells screened at least partially in HSU-2 (W-119, W-906, W-1303, W-1306, and W-1308) within and downgradient from the East Traffic Circle Landfill were analyzed for the same elements as the Taxi Strip Area. No concentrations of plutonium, americium, or radium radioisotopes were detected above the radiological laboratory's minimum detectable activities. Concentrations of tritium remained well below the drinking water MCL. Of the trace metals (copper, lead, and zinc), only zinc was detected in any of these seven monitoring wells during 2006. A zinc concentration of 22 μg/L was reported for well W-906, far below the secondary MCL for zinc in drinking water (5000 μg/L).

Although the National Ignition Facility (NIF) has not yet begun full operations, LLNL measures pH, conductivity, and tritium concentration of groundwater quality to establish a

baseline prior to the start of operations. During 2006, tritium analyses were conducted on groundwater samples collected from wells W-653 and W-1207 (screened in HSU-3A and HSU-2, respectively) downgradient of NIF. Samples were obtained downgradient from the Decontamination and Waste Treatment Facility (DWTF) from wells W-007, W-593, and W-594 (screened in HSU-2/3A, HSU-3A, and HSU-2, respectively) during 2006 and were analyzed for tritium.

Monitoring results from the wells near NIF and DWTF showed no detectable concentrations of tritium, above the limit of sensitivity of the analytical method, in the groundwater samples collected during 2006. Monitoring will continue near these facilities to determine baseline conditions.

Area 514 and the hazardous waste/mixed waste storage facilities around Building 612 are also a potential source of contamination. The area and facilities are monitored by wells W-270 and W-359 (both screened in HSU-5), and well GSW-011 (screened in HSU-3A). Groundwater from these wells was sampled and analyzed for general minerals, gross alpha, gross beta, americium-241, plutonium-238, plutonium-239, radium-226, and tritium in 2006. No significant contamination was detected in the groundwater samples collected from wells W-270, W-359, or GSW-011 downgradient from those areas in 2006.

Groundwater samples were obtained from monitoring well W-307 (screened in HSU-1B). This location, downgradient from a fume hood vent on the roof of Building 322 (a metal plating shop), is an area where releases of metals to the ground have occurred. Soil samples previously obtained from the area showed elevated concentrations (in comparison with the Livermore site's background levels) of total chromium, copper, lead, nickel, zinc, and occasionally other metals. LLNL removed contaminated soils near Building 322 in 1999 and replaced them with clean fill. The area was then paved over, making it less likely that metals would migrate from the site. In 2006, the monitoring results for well W-307 showed only slight variations from the concentrations reported in recent years.

Groundwater samples were obtained downgradient from a location where sediments containing metals (including cadmium, chromium, copper, lead, mercury, and zinc) had accumulated in a storm water catch basin near Building 253. The accumulated sediment in the catch basin is a potential source of several metals (Jackson 1997). In 2006, the samples obtained from monitoring wells W-226 and W-306 (screened in HSU-1B and HSU-2, respectively) contained dissolved chromium at elevated concentrations, but concentrations were essentially unchanged from last year. Concentrations of chromium(VI) were 27 μg/L at well W-226 and 38 μg/L at well W-306. No concentration of either dissolved chromium or chromium(VI) was greater than the MCL of 50 μg/L for total chromium in drinking water.

Additional surveillance groundwater sampling locations, established in 1999, are in areas surrounding the Plutonium Facility and Tritium Facility. Potential contaminants include plutonium and tritium from these facilities, respectively. Plutonium is much more likely to bind to the soils than migrate into the groundwater. Tritium, as HTO, can migrate into groundwater if spilled in sufficient quantities. Upgradient of these facilities, well W-305

is screened in HSU-2; downgradient wells W-101, W-147, and W-148 are screened in HSU-1B. Groundwater samples collected from these wells during 2006 showed no detectable concentration, above the limit of sensitivity for the analytical method, of either plutonium-238 or plutonium-239+240.

In August 2000, relatively elevated tritium activity was detected in the groundwater sampled at well W-148 (115 ± 5.0 Bq/L [3100 ± 135 pCi/L]). The activity was most likely related to local infiltration of storm water containing elevated tritium activity. Tritium activities in groundwater in this area have been at or near the same level since then, but both samples collected from well W-148 in 2006 showed lower values—approximately one half the August 2000 value (64 Bq/L and 57 Bq/L). LLNL continues to collect groundwater samples from these wells periodically for surveillance purposes, primarily to demonstrate that tritium and plutonium contents remain below environmental levels of concern.

5.4.2 Site 300 and Environs

For surveillance and compliance groundwater monitoring at Site 300, LLNL uses on-site DOE CERCLA wells and springs and off-site private wells and springs. Representative groundwater samples are obtained at least once a year at every monitoring location, and the samples are analyzed for various elements (primarily metals), a wide range of organic compounds, general radioactivity (gross alpha and gross beta), uranium activity, and tritium activity. Groundwater from the shallowest water-bearing zone is the target of most of the monitoring because it would be the first to show contamination from surface and sub-surface operations at Site 300.

Twelve groundwater monitoring locations are off site (see **Figure 5-12**). Two, MUL2 and VIE1, are springs near the northern boundary of Site 300. Off-site surveillance well VIE2 is 6 km west of Site 300 in the upper reaches of the Livermore Valley watershed. Eight off-site surveillance locations are wells near the southern boundary of Site 300 in or adjacent to the Corral Hollow Creek floodplain.

On-site wells are used to monitor closed landfills, a closed explosives burn pit, and two operational, connected sewer ponds. The closed landfills—identified as Pit 1, Pit 2, Pit 7 Complex, Pit 8, and Pit 9—are in the northern portion of Site 300 in the Elk Ravine drainage area, while Pit 6, the former burn pit (Building 829), and the sewage ponds are in the southern portion of Site 300 in the Corral Hollow Creek drainage area. Two on-site water supply wells, identified as Wells 18 and 20, are also used for surveillance monitoring purposes. Well 20 provides potable water to the site. Well 18 is maintained as a standby potable supply well.

Brief descriptions of the Site 300 groundwater monitoring networks that are reported in this chapter are given below. Networks of wells within the Elk Ravine drainage area are described first, followed by the well networks in the Corral Hollow Creek drainage area. Subsets of CERCLA wells, installed mainly for site characterization, have been selected for

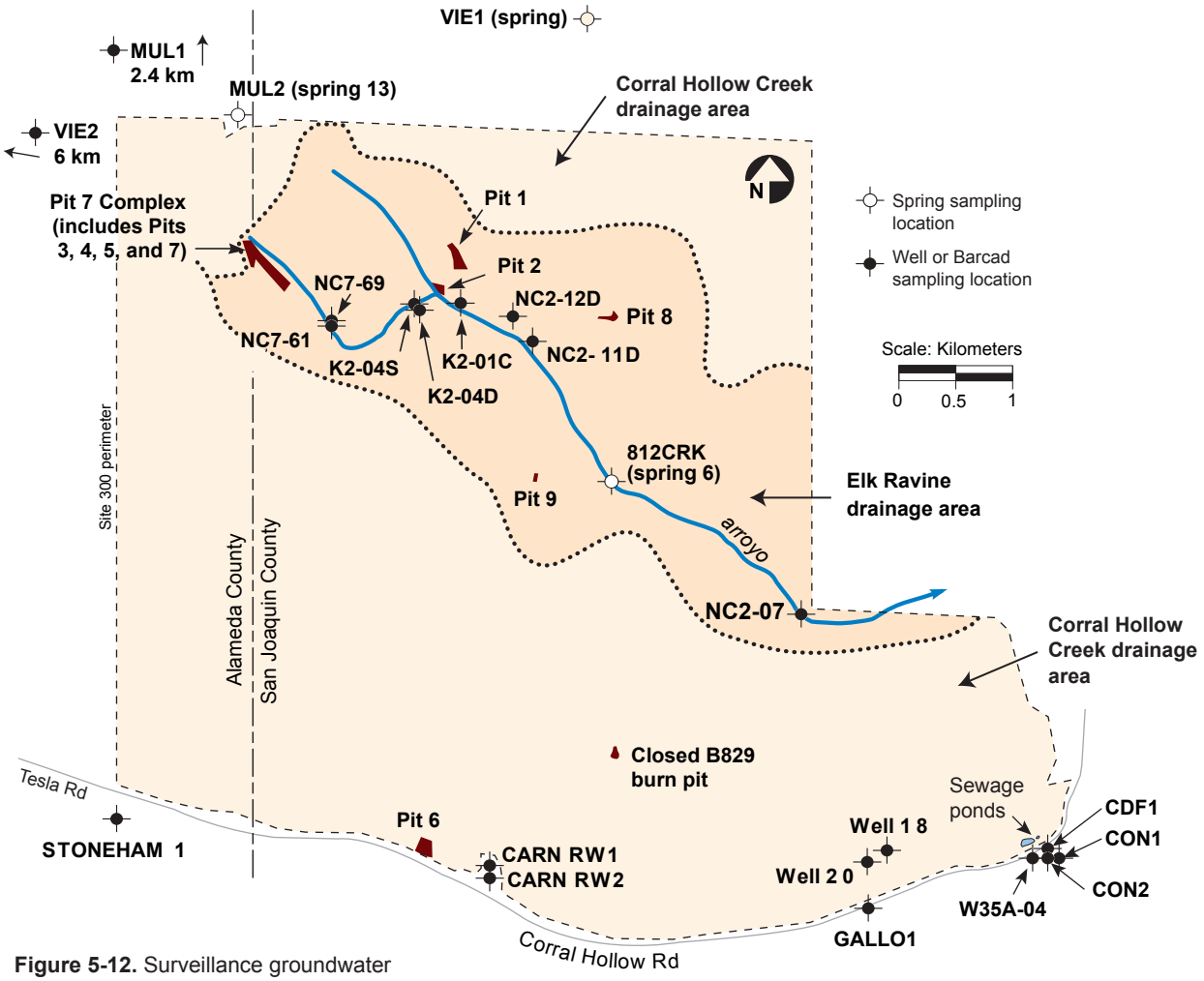

Figure 5-12. Surveillance groundwater wells and springs at Site 300, 2006.

compliance and surveillance monitoring use based on their locations and LLNL's general understanding of local geologic and hydrogeologic conditions at Site 300. (**Chapters 1** and **8** include summaries of Site 300 hydrology and stratigraphy, respectively. All analytical data from 2006 are provided in **Appendix B**, **Section B.5**.)

5.4.2.1 Elk Ravine Drainage Area

The Elk Ravine drainage area, a branch of the Corral Hollow Creek drainage system, includes most of northern Site 300 (see **Figure 5-12**). Storm water runoff in the Elk Ravine drainage area collects in arroyos and quickly infiltrates into the ground. Groundwater from wells in the Elk Ravine drainage area is monitored for COCs because of the system of surface and underground flows that connects the entire Elk Ravine drainage area. The area contains eight closed landfills known as Pits 1 through 5 and 7 through 9 and firing tables where explosives tests are conducted. None of the closed landfills has a liner, which is consistent with the disposal practices when the landfills were constructed. The following descriptions

of monitoring networks within Elk Ravine begin with the headwaters area and proceed downstream. (See **Chapter 8** for a review of groundwater contamination in this drainage area as determined from numerous CERCLA remedial investigations.)

Pit 7 Complex. Monitoring requirements for the Pit 7 landfill, which was closed under the Resource Conservation and Recovery Act of 1976 (RCRA) in 1993, are specified in WDR 93-100 administered by the CVRWQCB (1993, 1998a) and in *LLNL Site 300 RCRA Closure and Post-Closure Plans—Landfill Pits 1 and 7* (Rogers/Pacific Corporation 1990). The main objective of this monitoring is the early detection of any new release of COCs from Pit 7 to groundwater.

The Pit 7 Complex area is at an elevation of about 400 meters (m) above sea level and is in the highest portion of the Elk Ravine drainage area. The complex consists of four adjacent landfills identified as Pits 3, 4, 5, and 7 (see **Figure 5-13**). From 1963 to 1988, the landfills received waste gravels and debris from hydrodynamic tests of explosive devices conducted on firing tables at Site 300. The gravels contained concrete, cable, plastic, wood, tritium, uranium, beryllium, lead, and other metals in trace amounts. In 1988, 9440 cubic meters (m^3) of gravel were removed from six firing tables at Site 300 and placed in Pit 7 (Lamarre and Taffet 1989) and were the last solid wastes to be placed in any landfill at Site 300.

For compliance purposes, LLNL obtained groundwater samples quarterly during 2006 from the Pit 7 monitoring well network. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and volatile organic compounds (VOCs). Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection.

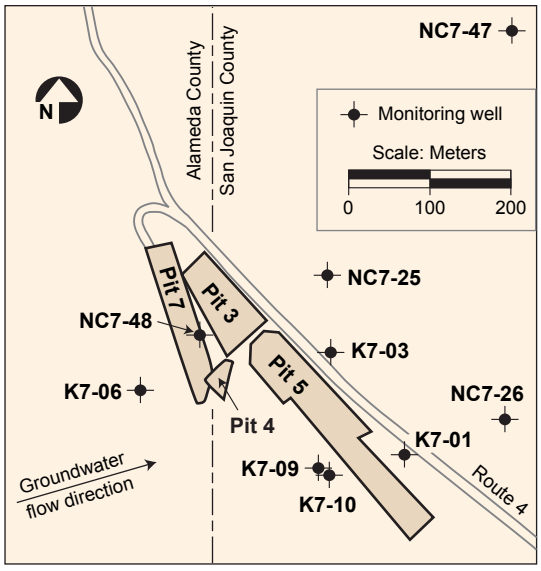

Figure 5-13. Pit 7 compliance groundwater monitoring wells, Site 300, 2006.

No new release of COCs to groundwater from Pit 7 was evident in the chemical data obtained during 2006. The COCs detected in groundwater include several metals, depleted uranium, tritium, and several VOCs and are associated with releases that occurred prior to 2006. The primary sources of COCs detected by the network of Pit 7 monitoring wells are the closed landfills known as Pits 3 and 5, which are adjacent to Pit 7 (see **Figure 5-13**). Natural sources in the rocks and sediments surrounding Pit 7 also have contributed arsenic, barium, uranium, and, possibly nitrate to the groundwater. In the past, especially during the El Niño winters of 1982/1983 and 1997/1998, excessive seasonal rainfall caused groundwater levels to rise into Pit 3 and Pit 5 from beneath, leading to

the release of COCs, mainly tritium in the form of HTO. Because of reduced rainfall since 1998, groundwater elevations have generally fallen at Site 300, thus reducing the potential for releases to occur by this mechanism. CERCLA modeling studies indicate that tritium and other COCs released in the past will not reach off-site aquifers at concentrations above MCLs. See **Chapter 8** for a review of CERCLA activities regarding groundwater contamination in the upper reaches of the Elk Ravine drainage area. For a detailed account of Pit 7 compliance monitoring during 2005, including tables and graphs of groundwater COC analytical data, see Campbell and MacQueen (2007).

Elk Ravine. Groundwater samples were obtained on various dates in 2006 from the widespread Elk Ravine surveillance monitoring network (see **Figure 5-12**). Samples were analyzed for inorganic constituents (mostly metallic elements), VOCs, general radioactivity (gross alpha and beta), tritium and uranium activity, and explosive compounds (HMX and RDX).

No new release of COCs from LLNL operations in Elk Ravine to groundwater is indicated by the chemical and radioactivity data obtained during 2006. The major source of contaminated groundwater beneath Elk Ravine is from historical operations in the Building 850 firing table area (Webster-Scholten 1994; Taffet et al. 1996). Constituents that are measured as part of the Elk Ravine drainage area surveillance monitoring network are listed in **Appendix C**.

Concentrations of arsenic range up to 42 μg/L (well NC2-07) in Elk Ravine monitoring wells. Earlier CERCLA characterization studies determined that the arsenic is from natural sources, particularly from the dissolution of the mineral arsenopyrite, which is a component of the underlying volcanogenic sediments and sedimentary rocks (Raber and Carpenter 1983). It should be noted that there are no wells in this area that are used for potable domestic, livestock, or industrial water supply. However, a perennial spring in Elk Ravine (location 812CRK, see **Figure 5-12**), which is used by the indigenous wildlife, contains concentrations of naturally occurring arsenic (31 μg/L arsenic in 2006).

An elevated tritium activity was detected in one of five shallow groundwater surveillance samples collected from wells in Elk Ravine during 2006 (well NC7-61, 1200 Bq/L [3.2×10^4 pCi/L]). Tritium, as HTO, has been released in the past in the vicinity of Building 850. The largest HTO plume, which extends eastward more than 1 km from a source beneath the Building 850 firing table area to the vicinity of Pits 1 and 2, is confined to shallow depths in the Neroly lower blue sandstone unit and overlying alluvium.

The majority of the Elk Ravine surveillance network tritium measurements made during 2006 support earlier CERCLA studies that show that the tritium in the plume is diminishing because of natural decay and dispersion (Ziagos and Reber-Cox 1998). For example, tritium activity in groundwater at well NC7-61 has decreased from 6500 Bq/L (1.8×10^5 pCi/L) in 1996 to 1200 Bq/L (3.2×10^4 pCi/L) in 2006. CERCLA modeling studies indicate that the tritium will decay to background levels before it can reach a site boundary. Note that the tritium plume has not yet reached the surveillance monitoring perennial spring location

812CRK, which is approximately 1.6 km upstream from where the Site 300 boundary crosses Elk Ravine.

Groundwater surveillance measurements of gross alpha, gross beta, and uranium radioactivity in Elk Ravine were all low in 2006 and indistinguishable from background levels. (Note that gross beta measurements do not detect the low-energy beta emission from tritium decay.) Additional detections of nonradioactive elements, including arsenic, barium, chromium, selenium, vanadium, and zinc, were all within the natural ranges of concentrations typical of groundwater elsewhere in the Altamont Hills.

Pit 1. Monitoring requirements for the Pit 1 landfill, which was closed under RCRA in 1993, are also specified in WDR 93-100 administered by the CVRWQCB (1993, 1998a) and in Rogers/Pacific Corporation (1990). The main objective of this monitoring is the early detection of any release of COCs from Pit 1 to groundwater.

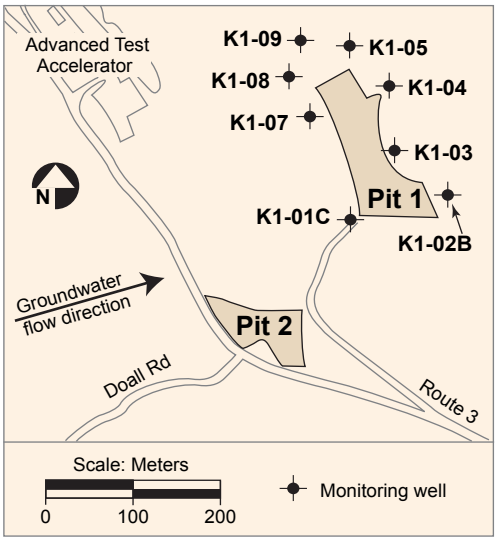

Figure 5-14. Pit 1 compliance groundwater monitoring wells, Site 300, 2006.

Pit 1 lies in the Elk Ravine drainage area about 330 m above sea level. The Pit 1 landfill and the positions of the eight groundwater wells used to monitor it are shown in **Figure 5-14**. The eight wells are K1-01C, K1-02B, K1-03, K1-04, K1-05, K1-07, K1-08, and K1-09.

As planned for compliance purposes, LLNL obtained groundwater samples quarterly during 2006 from the Pit 1 monitoring well network. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and VOCs (EPA Methods 601 and 8260). Additional annual analyses were conducted on groundwater samples for extractable organics (EPA Method 625), as well as pesticides and PCBs (EPA Method 608). Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of quarterly sample collection.

No release of COCs to groundwater from Pit 1 was evident in the 2006 monitoring data. A detailed account of Pit 1 compliance monitoring during 2006, including tables and graphs of groundwater COC analytical data, is in Campbell and MacQueen (2007).

During 2006, average tritium activities above analytical background levels (about 4 Bq/L [100 pCi/L]) were measured in the groundwater at Pit 1 monitoring wells K1-01C (26 Bq/L [693 pCi/L]), K1-02B (147 Bq/L [3965 pCi/L]), K1-03 (35 Bq/L [951 pCi/L]), K1-04 (8 Bq/L [221 pCi/L]), K1-08 (7 Bq/L [183 pCi/L]), and K1-09 (5 Bq/L [140 pCi/L]). The tritium activity in the groundwater sampled at these wells represents a distal lobe of the Building 850 tritium plume. Measurements of radium, thorium, and uranium made during

2006 in groundwater samples from Pit 1 compliance monitoring wells showed low activities indistinguishable from background levels.

The VOC 1,1,2-trichloro-1,2,2-trifluoroethane (Freon-113) decreased from a maximum concentration of 140 μg/L measured in 1999 to 51 μg/L in 2006 in groundwater samples at Pit 1 monitoring well K1-09. Maximum annual Freon-113 concentrations at groundwater monitoring wells K1-05 and K1-08 were 18 μg/L and 34 μg/L, respectively. The drinking water MCL for this VOC is 1200 μg/L. CERCLA investigations have linked the Freon-113 detection in Pit 1 monitoring wells to area source at Building 865, about 300 m northwest of Pit 1 (Webster-Scholten 1994; Taffet et al. 1996; Ferry and Holtzapple 2006).

5.4.2.2 Corral Hollow Creek Drainage Area

Pit 6. Compliance monitoring requirements for the closed Pit 6 landfill in the Corral Hollow Creek drainage area are specified in Ferry et al. (1998, 2002). The closed Pit 6 landfill covers an area of about 1 ha (2.5 ac) at an elevation of approximately 215 m above sea level. From 1964 to 1973, approximately 1500 m^3 of solid wastes were buried there in nine separate trenches. The trenches were not lined, consistent with historical disposal practices. Three larger trenches contain 1300 m^3 of solid waste that includes empty drums, glove boxes, lumber, ducting, and capacitors. Six smaller trenches contain 230 m^3 of biomedical waste, including animal carcasses and animal waste. During 1997, a multilayered cap was constructed over all the trenches, and a storm water drainage control system was installed around the cap. The cap and the drainage control system are engineered to keep rainwater from contacting the buried waste (Ferry et al. 1998).

The Pit 6 disposal trenches were constructed in Quaternary terrace deposits (Qt) north of the Corral Hollow Creek floodplain. Surface runoff from the pit area flows southward to Corral Hollow Creek. The Carnegie-Corral Hollow Fault zone extends beneath the southern third of Pit 6. The northern limit of the fault zone is shown in **Figure 5-15**. Beneath the northern two thirds of Pit 6, groundwater flows south–southeast, following the inclination of the underlying sedimentary rocks. Groundwater seepage velocities are less than 10 m/y. Depths to the water table range from 10 to 20 m. Beneath the southern third of Pit 6, a trough containing terrace gravel within the fault zone provides a channel for groundwater to flow southeast, parallel to the Site 300 boundary fence (Webster-Scholten 1994).

Two Pit 6 groundwater monitoring programs, which operate under CERCLA, ensure compliance with all regulations. They are (1) the Detection Monitoring Program (DMP), designed to detect any new release of COCs to groundwater from wastes buried in the Pit 6 landfill, and (2) the Corrective Action Monitoring Program (CAMP), which monitors the movement and fate of historical releases. **Figure 5-15** shows the locations of Pit 6 and the wells used to monitor the groundwater there. To comply with monitoring requirements, LLNL obtained groundwater samples monthly, quarterly, semiannually, and annually during 2006 from specified Pit 6 monitoring wells. DMP samples were obtained quarterly and were

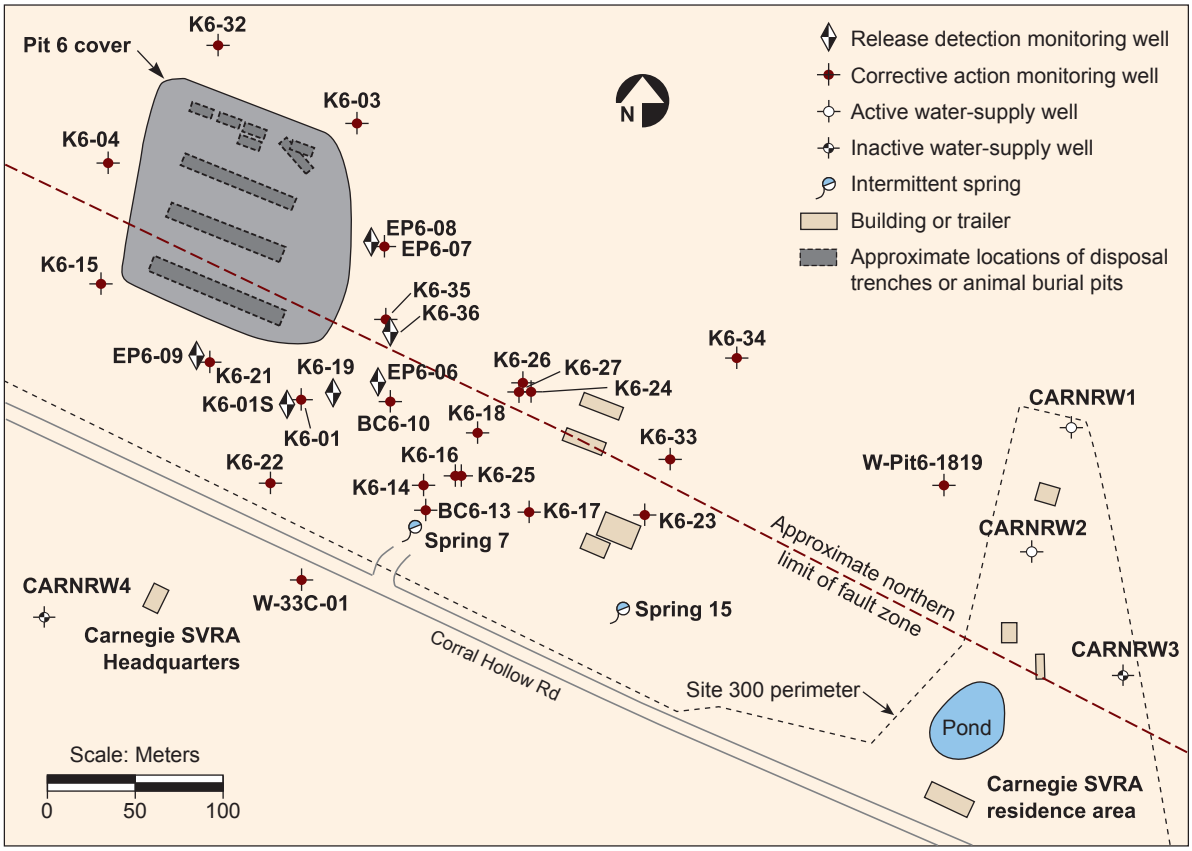

Figure 5-15. Pit 6 compliance groundwater monitoring wells and springs, Site 300, 2006.

analyzed for beryllium and mercury, general radioactivity (gross alpha and beta), tritium and uranium activity, specified VOCs, nitrate and perchlorate. CAMP samples were measured for VOCs, tritium activity, nitrate and perchlorate. Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection.

No new release of COCs from Pit 6 was indicated by the chemical analyses of groundwater samples obtained from Pit 6 monitoring wells during 2006. COCs that were released prior to constructing an impermeable cap over the closed landfill in 1997 continued to be detected in the groundwater at low concentrations during 2006. These COCs include tritium, perchlorate, trichloroethylene (TCE), perchloroethylene (PCE), and cis-1,2-dichloroethene (cis-1,2-DCE). All contaminant plumes associated with Pit 6 are confined to shallow depths. None has been detected beyond the Site 300 boundary. For a detailed account of Pit 6 compliance monitoring during 2006, including tables of groundwater analytical data and maps showing the distribution of COC plumes, see Campbell and Taffet (2007).

Building 829 Closed High Explosives Burn Facility. Compliance monitoring requirements for the closed burn pits in the Corral Hollow Creek drainage area are specified in Mathews and Taffet (1997), and in LLNL (2001), as modified by DTSC (2003).

The former Burn Facility, part of the Building 829 Complex, is located on a ridge within the southeast portion of Site 300 at an elevation of about 320 m above sea level. The facility included three shallow, unlined pits constructed in unconsolidated sediments that cap the ridge (Tps formation). The facility was used to thermally treat explosives process waste generated by operations at Site 300 and similar waste from explosives research operations at the Livermore site. The facility was covered with an impervious cap in 1998 following RCRA guidance.

Surface water drains southward from the facility toward Corral Hollow Creek. The nearest site boundary lies about 1.6 km to the south at Corral Hollow Road. Stratified rocks of the Neroly (Tn) Formation underlie the facility and dip southeasterly. Two water-bearing zones exist at different depths beneath the facility. The shallower zone, at a depth of about 30 m, is perched within the Neroly upper siltstone/claystone aquitard ($Tnsc_2$). The deeper zone, at a depth of about 120 m, represents a regional aquifer within the Neroly upper sandstone member ($Tnbs_2$). (See **Figure 8-5** for Site 300 stratigraphy.)

Based on groundwater samples recovered from boreholes, CERCLA remedial investigations have determined that the perched groundwater near the Burn Facility was contaminated with VOCs, primarily TCE, but that the deeper regional aquifer was free of any contamination stemming from operation of the facility (Webster-Scholten 1994). Subsequent assays of soil samples obtained from shallow boreholes prior to closure revealed that low concentrations of explosives compounds, VOCs, and metals exist beneath the burn pits (Mathews and Taffet 1997). Conservative transport modeling indicates that the shallow contamination will not adversely impact the regional aquifer primarily because its downward movement is blocked by more than 100 m of unsaturated Neroly Formation sediments that include interbeds of claystone and siltstone.

Beginning in 1999, LLNL implemented the intensive groundwater monitoring program for this area described in the post-closure plan (Mathews and Taffet 1997) to track the fate of contaminants in the soil and the perched water-bearing zone and to monitor the deep regional aquifer for the appearance of any potential contaminants from the Burn Facility. This monitoring program remained in effect through the first quarter of 2003, at which time LLNL began implementing the provisions specified in the *Hazardous Waste Facility Post-Closure Permit for the B829 Facility* (DTSC 2003). Following the guidance outlined in the DTSC technical completeness assessment (DTSC 2002), LLNL installed one additional groundwater monitoring well at the point of compliance within 3 m of the edge of the capped High Explosive Open Burn Treatment Facility. This well, W-829-1938, was screened in the regional aquifer, the uppermost aquifer beneath the Building 829 facility. Since the first quarter of 2004, and continuing through 2006, well W-829-1938 has been used for quarterly collection of groundwater samples from the regional aquifer as part of the permit-specified

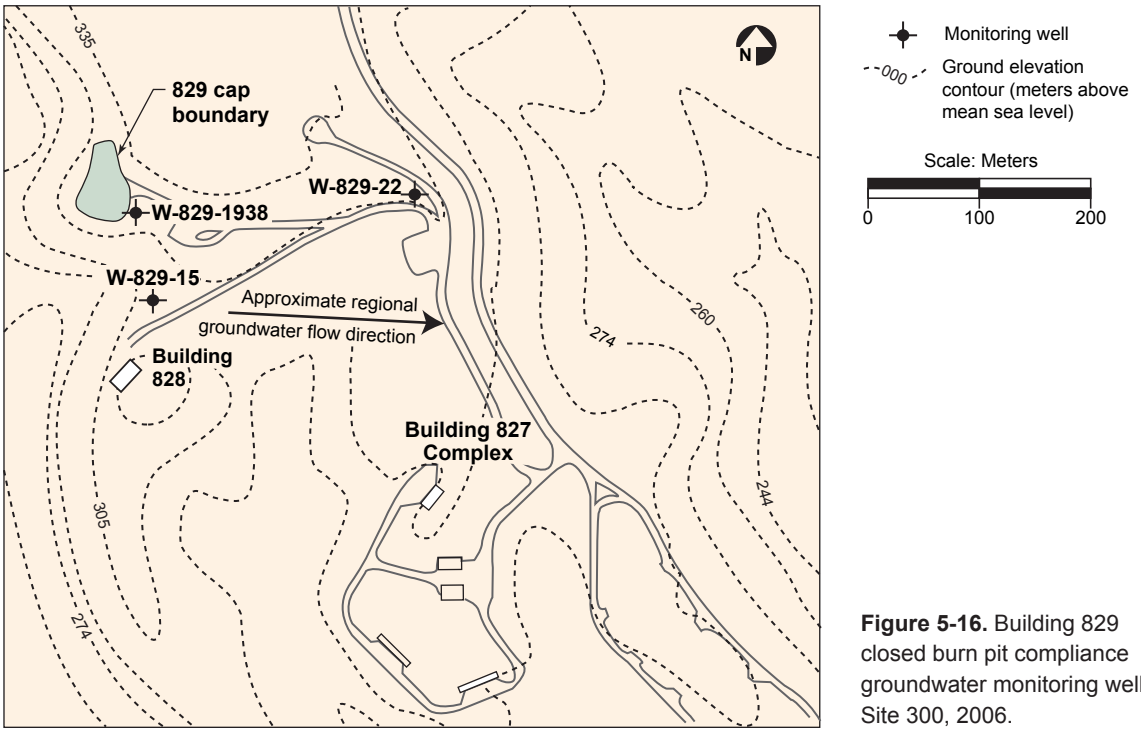

Figure 5-16. Building 829 closed burn pit compliance groundwater monitoring wells, Site 300, 2006.

monitoring network (see **Figure 5-16**). Also shown in **Figure 5-16** are two previously existing wells, W-829-15 and W-829-22, which were each sampled once in 2006 in accordance with the DTSC-approved change in sampling frequency (from quarterly to annual) for these two wells (DTSC 2005).

As planned for compliance purposes, LLNL obtained groundwater samples during 2006 from the Building 829 monitoring well network. Groundwater samples from the wells screened in the deep regional aquifer were analyzed for inorganics (mostly metals), general minerals, turbidity, explosive compounds (HMX, RDX, and TNT), VOCs (EPA Method 624), extractable organics (EPA Method 625), pesticides (EPA Method 608), herbicides (EPA Method 615), general radioactivity (gross alpha and beta), radium activity, total organic carbon (TOC), total organic halides (TOX), and coliform bacteria.

During 2006, there were no confirmed COC detections above their respective statistical limits in groundwater samples from any of the three monitoring wells. Among the inorganic constituents, the metal COCs that were detected showed concentrations that are not significantly different from background concentrations for the deep aquifer beneath the High Explosives (HE) Process Area. Similarly, all results for gross alpha and gross beta (the radioactive COCs) were below their statistical limit values. The COC perchlorate was initially reported in one sample from well W-829-1938, but this result was subsequently invalidated. There were no organic or explosive COCs detected above reporting limits in any samples.

No new release of COCs to groundwater from the closed Burn Facility was indicated by the monitoring data obtained during 2006. For a detailed account of compliance monitoring of the closed burn pit during 2006, including tables and graphs of groundwater COC analytical data, see Revelli (2007b).

Water Supply Well. Water supply Well 20, located in the southeastern part of Site 300 (see **Figure 5-12**), is a deep, high-production well. The well is screened in the Neroly lower sandstone aquifer ($Tnbs_1$) and can produce up to 1500 liters per minute (L/min) of potable water. As planned for surveillance purposes, LLNL obtained groundwater samples quarterly during 2006 from Well 20. Groundwater samples were analyzed for inorganic COCs (mostly metals), VOCs, general radioactivity (gross alpha and gross beta), and tritium activity.

Quarterly measurements of groundwater from Well 20 did not differ significantly from previous years. As in past years, this Site 300 primary potable water supply well showed no evidence of contamination. Gross alpha, gross beta, and tritium activities were very low and are indistinguishable from background level activities.

5.4.2.3 Off-site Surveillance Wells and Springs

As planned for surveillance purposes, LLNL obtained groundwater samples from two off-site springs and ten off-site wells during 2006. With the exception of one well, all off-site monitoring locations are near Site 300. The exception, well VIE2, is located at a private residence 6 km west of the site. It represents a typical potable water supply well in the Altamont Hills. One stock watering well, MUL1, and two stock watering springs, MUL2 and VIE1, are adjacent to Site 300 on the north. Eight wells, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STONEHAM1, and W35A-04, are adjacent to the site on the south (see **Figure 5-12**). Well W-35A-04 is a DOE CERCLA well that was installed off-site for monitoring purposes only. The remaining seven wells south of Site 300 are privately owned and were constructed to supply water either for human consumption, stock watering, or fire suppression. They are monitored to determine the concentrations of dissolved constituents in the groundwater beneath the Corral Hollow Creek floodplain.

Groundwater samples were obtained quarterly during 2006 at six of the off-site surveillance well locations south of Site 300. As planned, CARNRW1 and CON2 samples were analyzed for VOCs; samples from well CARNRW1 were also sampled for perchlorate and tritium. Samples from CARNRW2, CDF1, CON1, and GALLO1 were analyzed quarterly for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), tritium activity, explosive compounds (HMX and RDX), and VOCs (EPA Method 502.2). Additional annual analyses were conducted on third-quarter samples for uranium activity and extractable organic compounds (EPA Method 625) for samples collected from CARNRW2 only.

Groundwater samples were obtained once (annually) during 2006 from the remaining off-site surveillance monitoring locations—MUL1, MUL2, and VIE1 (north of Site 300);

VIE2 (west of Site 300); and STONEHAM1 and W-35A-04 (south of Site 300). Samples were analyzed for inorganic COCs (metals, nitrate, and perchlorate), general radioactivity (gross alpha and beta), tritium and uranium activity, explosive compounds (HMX and RDX), VOCs, and extractable organic compounds (EPA Method 625).

Generally, no COC attributable to LLNL operations at Site 300 was detected in the off-site groundwater samples. Arsenic and barium were widely detected at the off-site locations, but their concentrations were below MCLs and their occurrence is consistent with natural sources in the rocks. Scattered detections of metals are probably related to metals used in pumps and supply piping. Radioactivity measurements of off-site groundwater are generally indistinguishable from background activities.

5.4.3 Environmental Impact on Groundwater

Groundwater monitoring at the Livermore site and Site 300 and their environs indicates that LLNL operations have minimal impact on groundwater beyond the site boundaries. During 2006, neither radioactivity nor concentrations of elements or compounds detected in groundwater that could be affected by LLNL activities were confirmed to be above potable water MCLs.

5.5 Other Monitoring Programs

5.5.1 Rainwater

Rainwater is sampled and analyzed for tritium activity in support of DOE Order 5400.5, Radiation Protection of the Public and the Environment. LLNL collects rainwater samples according to written, standardized procedures that are summarized in Woods (2005). Rainwater is collected in stainless-steel buckets at fixed locations. The buckets are in open areas and mounted about 1 m above the ground to prevent collection of splashback water. Rainwater samples are decanted into 250-mL amber glass bottles with Teflon-lined lids. The tritium activity of each sample is measured at a contracted laboratory by a scintillation counting method equivalent to EPA Method 906 that has a low reporting limit of about 3.7 Bq/L (100 pCi/L). All analytical results are provided in **Appendix B**, **Section B.7**.

5.5.1.1 Livermore Site and Environs

Historically, the tritium activity measured in rainwater in the Livermore Valley was caused by atmospheric emissions of HTO from stacks at LLNL's Tritium Facility, and prior to 1995, from the former Tritium Research Laboratory at Sandia/California. During 2006, tritium activity in air-moisture and thence in rainwater at the Livermore site and in the Livermore Valley resulted primarily from atmospheric emissions of HTO from stacks at the Tritium Facility. Atmospheric emissions of tritium from the Tritium Facility are shown in **Figure 4-4**.

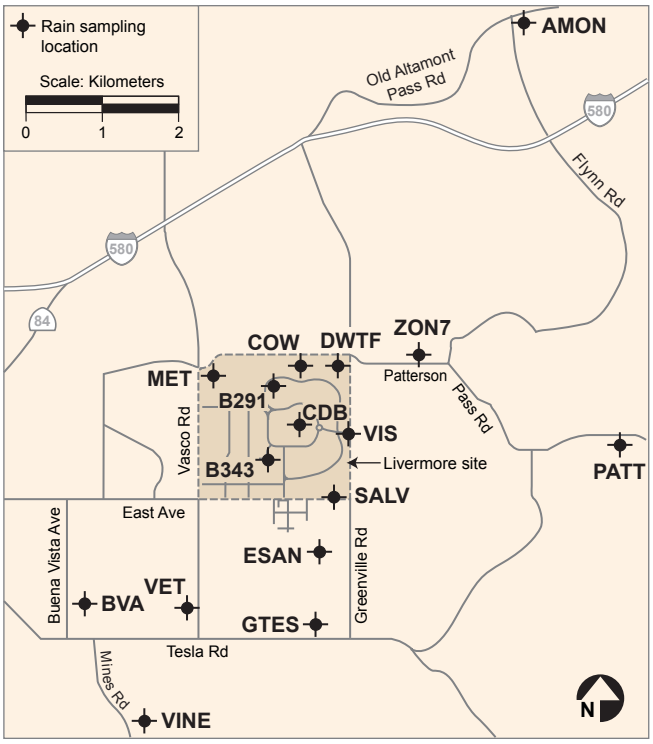

Figure 5-17. Rain sampling locations, Livermore site and Livermore Valley, 2006.

Other sources include the Waste Management Area (WMA) at Building 612 and the DWTF (see **Chapter 4**).

Rain sampling locations are shown in **Figure 5-17**. The fixed locations are used to determine the areal extent of detectable tritium activity in rainwater. During 2006, LLNL collected sets of rainwater samples following two rain events in the Livermore Valley and two rain events at Site 300. All of the rainwater sampling dates correspond to storm water runoff sampling.

Although Livermore site rainwater has exhibited elevated tritium activities in the past (Gallegos et al. 1994), during 2006, no on-site measurement of tritium activity was above the MCL of 740 Bq/L (20,000 pCi/L) established by the EPA for drinking water. As in past years, the on-site rainwater sampling location B343 showed the highest tritium activity for the year, 13 Bq/L (351 pCi/L), for the rain event that was sampled on January 18. The maximum tritium activity measured in off-site rainwater samples during 2006 were estimated values below the minimum reporting limit of 3.7 Bq/L (100 pCi/L) in the rainwater sample obtained on March 3 and December 12 from locations AMON and VET, respectively (see **Figure 5-17**).

5.5.1.2 Site 300 and Environs

Three on-site locations (COHO, COMP, and TNK5) were positioned to collect rainfall for tritium activity measurements at Site 300 during 2006 (see **Figure 5-9**). During 2006, two rain events were sampled. As in past years, none of the rainwater samples from monitoring locations at Site 300 during 2006 showed tritium activities above the analytical laboratory reporting limit of 3.7 Bq/L (100 pCi/L).

5.5.2 Livermore Valley Surface Waters

LLNL conducts additional surface water surveillance monitoring in support of DOE Order 5400.5. Surface and drinking water near the Livermore site and in the Livermore Valley were sampled at the locations shown in **Figure 5-18** in 2006. Off-site sampling locations DEL, ZON7, DUCK, ALAG, SHAD, and CAL are surface water bodies; of these, DEL, ZON7, and CAL are also drinking water sources. GAS, ORCH2 (note that this ORCH2 is a shallower well adjacent to the location of the original ORCH well), and TAP are drinking

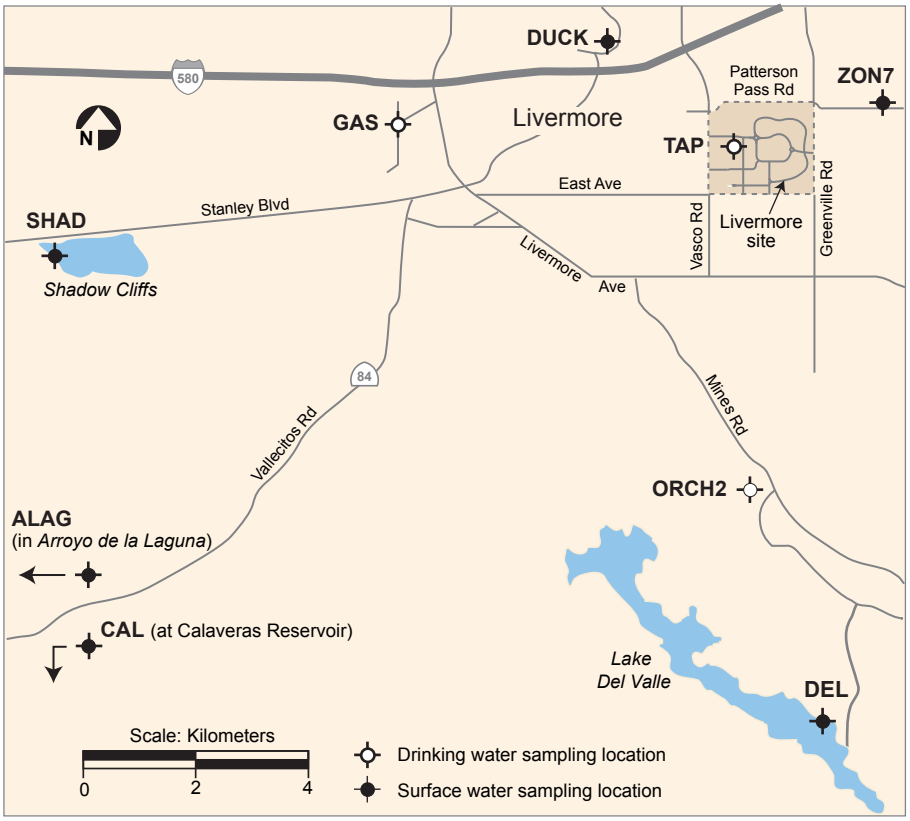

Figure 5-18. Livermore Valley surface and drinking water sampling locations, 2006.

water outlets. Radioactivity data from drinking water sources are used to calculate drinking water statistics (see **Table 5-13**).

Samples are analyzed according to written, standardized procedures summarized in Woods (2005). LLNL sampled these locations semiannually, in January and July 2006, for gross alpha, gross beta, and tritium. All analytical results are provided in **Appendix B**, **Section B.7**.

The median activity for tritium in surface and drinking waters was estimated from calculated values to be below the analytical laboratory's minimum detectable activities, or minimum quantifiable activities. The maximum tritium activity detected in any sample collected in 2006 was 5.62 Bq/L (152 pCi/L), less than 1% of the drinking water MCL. Median activities for gross alpha and gross beta radiation in surface and drinking water samples were both less than 5% of their respective MCLs. Maximum activities detected for gross alpha and gross beta radioactivity, respectively, were 0.042 Bq/L (1.13 pCi/L) and 0.206 Bq/L (5.58 pCi/L); both were less than 15% of their respective MCLs (see **Table 5-13**). Historically, concentrations of gross alpha and gross beta radiation have fluctuated around the laboratory's minimum detectable activities. At these very low levels, the counting error associated with the measurements is nearly equal to, or in many cases greater than, the calculated values so that no trends are apparent in the data.

Table 5-13. Radioactivity in surface and drinking waters in the Livermore Valley, 2006.[a]

Location	Metric	Tritium (Bq/L)	Gross alpha (Bq/L)	Gross beta (Bq/L)
All locations	Median	0.13	–0.004	0.085
	Minimum	–1.91	–0.037	0.012
	Maximum	5.62	0.042	0.206
	Interquartile range	2.14	0.022	0.047
Drinking water locations	Median	0.741	–0.010	0.071
	Minimum	–1.22	–0.027	0.012
	Maximum	5.18	0.003	0.124
	Interquartile range	3.49	0.014	0.051
	Drinking water MCL	740	0.555	1.85

(a) A negative number means the sample radioactivity was less than the background radioactivity.

Since 1988, when measurements began, water in the LLNL swimming pool had the highest tritium activities because it was close to tritium sources within LLNL. After the first quarter of 2004 and the draining of the swimming pool in July 2004, the Drainage Retention Basin (now Lake Haussmann), reported on elsewhere in this chapter, became the closest routinely monitored surface water to the Tritium Facility.

5.5.3 Lake Haussmann Release

Lake Haussmann (formerly known as the Drainage Retention Basin or DRB) was constructed and lined in 1992 after remedial action studies indicated that infiltration of storm water from the existing basin increased dispersal of groundwater contaminants. Located near the center of the Livermore site, Lake Haussmann can hold approximately 45.6 million L (37 acre-feet) of water. Previous LLNL environmental reports detail the history of the construction and management of Lake Haussmann (see Harrach et al. 1995, 1996, 1997). Beginning in 1997, LLNL discharges to Lake Haussmann included routine treated groundwater from areas TFD and TFE (see **Figure 8-1**), and from related portable treatment units. These discharges contribute a year-round source of water entering and exiting Lake Haussmann. The discharge rate is approximately 380 L/min. Storm water runoff still dominates wet weather flows through Lake Haussmann, but discharges from the treatment facilities now constitute a substantial portion of the total water passing through the lake.

The SFBRWQCB regulates discharges from Lake Haussmann. Jackson (2002) lists constituents of interest, sample frequencies, and discharge limits based on the Livermore site CERCLA Record of Decision (ROD) (U.S. DOE 1993), as modified by Berg et al. (1997). The ROD established discharge limits for all remedial activities at the Livermore site to

meet applicable, relevant, and appropriate requirements derived from laws and regulations identified in the ROD, including federal Clean Water Act, federal and state Safe Drinking Water Acts, and the California Porter-Cologne Water Quality Control Act. See **Appendix D** for the limits used.

The Lake Haussmann sampling program implements requirements established by the SFBRWQCB. The program consists of monitoring wet and dry weather releases for compliance with discharge limits and performing routine reporting. For purposes of determining discharge monitoring requirements and frequency, the wet season is defined as October 1 through May 31, the period when rain-related discharges usually occur (Galles 1997). Discharge limits are applied to the wet and dry seasons as defined in Berg et al. (1997) (wet season December 1 through March 31, dry season April 1 through November 30).

To characterize wet-season discharges, LLNL samples Lake Haussmann discharges at location CDBX and the Livermore site outfall at location WPDC during the first release of the rainy season, and from a minimum of one additional release (chosen in conjunction with storm water runoff sampling). During the dry season (June, July, August, September), samples are collected at the beginning of each discrete discharge event or monthly while discharge is continuous. Discharge sampling locations CDBX and WPDC are shown in **Figure 5-8**. LLNL collects samples at CDBX to determine compliance with discharge limits. Sampling at WPDC is performed to identify any change in water quality as Lake Haussmann discharges travel through the LLNL storm water drainage system and leave the site.

Written, standardized sample collection procedures are summarized in Woods (2005). State-certified laboratories analyze the collected samples for chemical and physical parameters. All analytical results are included in **Appendix B**, **Section B.7**.

In 2006, water releases typically occurred continuously to maintain relatively low nutrient levels in Lake Haussmann and because treatment facility discharge to Lake Haussmann exceeded the evaporation rate. Samples collected at CDBX and WPDC exceeded only the pH discharge limits. The higher pH readings seen in Lake Haussmann discharge samples during the summer correspond to the peak of the summer algal bloom within Lake Haussmann. During 2006, total dissolved solids and specific conductance continued to reflect the levels found in groundwater discharged to Lake Haussmann. While some metals were detected, none was above discharge limits. All organics and PCBs were below analytical detection limits. Pesticides, gross alpha, gross beta, and tritium levels were well below discharge limits.

LLNL collects and analyzes samples for acute fish toxicity using fathead minnow (*Pimphales promelas*) and for chronic toxicity using three species (fathead minnow, water flea daphnid [*Ceriodaphnia dubia*], and green algae [*Selanastrum capricomutum*]). LLNL collects acute toxicity samples at the first wet-season release and from the four dry season sampling events from location CDBX. Samples for chronic fish toxicity were collected at location CDBX at the first wet-season release. Aquatic bioassays for toxicity showed no effects in Lake Haussmann discharge water.

In early October 2006, the lake level was lowered and exits from the lake were sealed. On October 6, 2006, the piscicide (fish pesticide) rotenone was applied to Lake Haussmann to control non-native fish species and to protect native populations of the California red-legged frogs (*Rana aurora draytonii*). Water and sediment samples were collected from the lake according to a monitoring plan previously submitted to regulatory agencies. Rotenone and formulation by-products including rotenonelone, naphthalene, methyl pyrrolidone, and diethylene glycol ethyl ether were detected in early water samples, but none was detected after 17 days following the application. No water was released from the lake until November 27, 2006. No long-term side effects of rotenone application on water quality were observed, and all activities were performed in compliance with applicable water quality regulations. For a complete report and data, see Campbell et al. (2007).

5.5.4 Site 300 Drinking Water System

LLNL samples large-volume discharges from the Site 300 drinking water distribution system that reach surface water drainage courses in accordance with the requirements of WDR 5-00-175, NPDES General Permit No. CAG995001. The monitoring and reporting program that LLNL developed for these discharges was approved by the CVRWQCB.

Discharges that are subject to sampling under WDR 5-00-175 and their monitoring requirements are:

- Drinking water storage tanks: Discharges that have the potential to reach surface waters are monitored.
- System flushes: One flush per pressure zone per year is monitored for flushes that have the potential to reach surface waters.
- Dead-end flushes: All flushes that have the potential to reach surface waters and any discharge that continues for more than four months are monitored.

Discharges must comply with the effluent limits for residual chlorine and pH established by the permit; that is, residual chlorine must not be greater than 0.02 mg/L, and the pH must be between 6.5 and 8.5. Discharges are also visually monitored to ensure that no erosion results and no other pollutants are washed into surface waters. To meet the chlorine limit, drinking water system discharges with the potential to reach surface waters are dechlorinated.

Sample collection procedures are discussed in Mathews (2006). Grab samples are collected in accordance with written, standardized procedures summarized in Woods (2005). Residual chlorine and pH are immediately analyzed in the field using a spectrophotometer and calibrated pH meter, respectively.

Samples are collected at the point of discharge and at the point where the discharge flows into a surface water. If the discharge reaches Corral Hollow Creek, samples are collected at the upstream sampling location, CARW2, and the downstream sampling location, GEOCRK.

Small volumes of water (less than 7500 L [2000 gal]) were discharged in the first quarter of 2006 as a result of routine pressure tests conducted by the Site 300 fire department. Because of the nature of fire department activities, these small-volume discharges were not monitored. Monitoring results for the larger discharges associated with tank cleaning (April 2006), construction (July 2006), and maintenance (September 2006) activities are detailed in the quarterly self-monitoring reports to the CVRWQCB, as are results from the annual pressure zone testing. The annual testing, required by the CVRWQCB, was completed during the third quarter when LLNL conducted flushing of the drinking water system for water quality purposes. These system flush releases were monitored and met the effluent limits. All 2006 releases from the Site 300 drinking water system quickly percolated into the drainage ditches or streambed and did not reach Corral Hollow Creek, the potential receiving water.

5.5.5 Site 300 Cooling Towers

On August 4, 2000, the CVRWQCB rescinded WDR 94-131, NPDES Permit No. CA0081396, which had governed discharges from the two primary cooling towers at Site 300. The CVRWQCB determined that the cooling towers discharged to the ground rather than to surface water drainage courses. Therefore, the CVRWQCB will issue a new permit to incorporate the cooling tower discharges and other low-threat discharges going to ground. Pending the issuance of the new permit, LLNL continues to monitor the cooling tower wastewater discharges following the WDR 94-131 monitoring requirements at the direction of CVRWQCB staff.

Prior to April 2005, the two primary cooling towers at Buildings 801 and 836A regularly discharged to the ground. On April 13, 2005, the cooling tower at Building 836A was replaced with an air-cooled system; discharges and monitoring were discontinued at that time. The biweekly flow and quarterly total dissolved solids (TDS) and pH monitoring at cooling tower 801 continued through October 9, 2006, at which time the cooling tower 801 blowdown discharges were diverted to a recently constructed percolation pit, and the monitoring program was discontinued. The 13 secondary cooling towers routinely discharge to percolation pits under a waiver of Waste Discharge Requirements from the CVRWQCB. Cooling tower locations are shown in **Figure 5-19**.

Written, standardized sample collection procedures are summarized in Woods (2005). To determine the effects of the cooling tower 801 blowdown on Corral Hollow Creek, LLNL monitored pH quarterly, both upstream (background) and downstream of the cooling tower discharges, whenever the creek was flowing during the first three quarters of 2006. CARW2 is the upstream sampling location, and GEOCRK is the downstream sampling location (see **Figure 5-19**).

The GEOCRK sampling location is fed by sources from Site 300 and neighboring lands. Therefore, even when the upstream location is dry, there may be flow at GEOCRK. Field pH measurements, taken by LLNL using calibrated meters, are used to monitor Corral Hollow

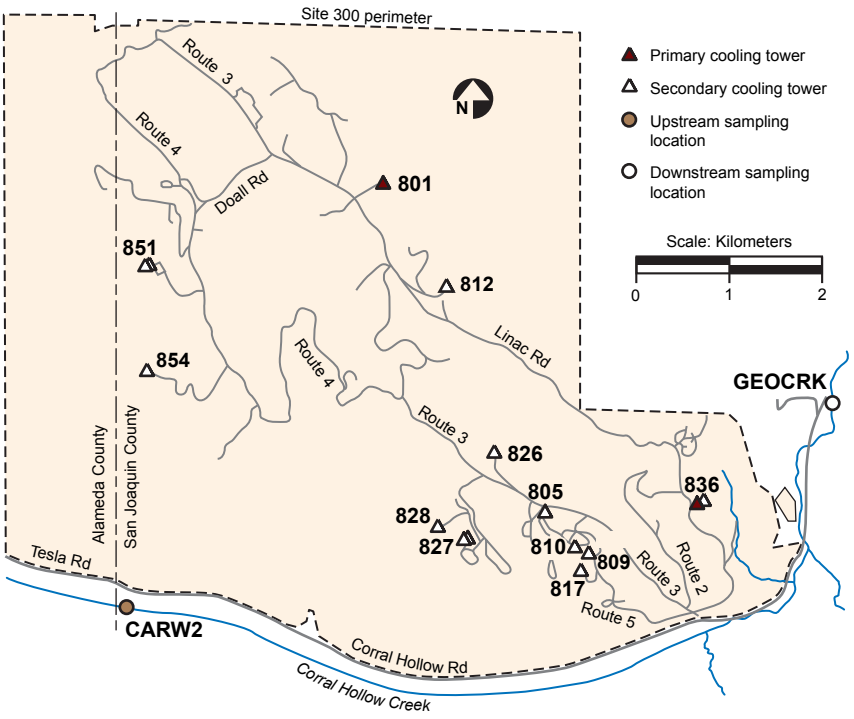

Figure 5-19. Cooling tower and receiving water monitoring locations, Site 300, 2006.

Creek. LLNL also performs the required visual observations that are recorded on field tracking forms along with the field pH measurements.

If the blowdown flow from any of the 13 secondary cooling towers is diverted to a surface water drainage course, the discharge is sampled for pH and TDS immediately. If the discharge continues, that location is monitored for the same constituents and on the same schedule as the primary cooling towers when discharging to the surface.

Monitoring results in 2006 indicated that all discharges from the Building 801 cooling tower were below the maximum TDS (2400 mg/L) and pH (10) values that were previously imposed for discharges to surface water drainage courses under WDR 94-131. The blowdown flow rates from this tower were typical of volumes reported in recent years. **Table 5-14** summarizes the data from the quarterly TDS and pH monitoring, as well as the biweekly measurements of blowdown flow rate.

The biweekly observations at CARW2 and GEOCRK generally reported flowing conditions for both sampling locations during the months of March, April, and May, 2006. The resulting field pH measurements were between 7.68 and 8.94 at the CARW2 location, and between 7.72 and 8.99 at GEOCRK. These results indicate essentially no change in pH between the upstream and downstream locations. During other months of 2006, prior to termination of the monitoring program in October, dry or no flow conditions were reported. Visual observations of Corral Hollow Creek were performed in the first three quarters of 2006, and no visible oil, grease, scum, foam, or floating suspended materials were noted.

Table 5-14. Summary data from monitoring of primary cooling tower 801, Site 300, 2006.

Test	Minimum	Maximum	Median	Interquartile range	No. samples
Total dissolved solids (mg/L)	1500	1700	1500	—[a]	3[b]
Blowdown (L/day)	0	15,475	5362	4603	20[b]
pH	9.0	9.1	9.0	—[a]	3[b]

(a) Too few data points to determine.

(b) Only 3 quarterly samples and 20 biweekly blowdown measurements were collected. The monitoring program at cooling tower 801 was discontinued October 9, 2006, after blowdown from that cooling tower was diverted to a percolation pit.

No drinking water or cooling tower water releases from Site 300 reached Corral Hollow Creek. There is no evidence of any adverse environmental impact on surrounding waters resulting from these LLNL activities during 2006.

5.5.6 Percolation Pits

Percolation pits designed to accept discharges from mechanical equipment are located at Site 300 Buildings 806A, 827A, 827C, 827D, and 827E. These discharges are permitted by WDR 96-248, which specifies monthly observations and monitoring requirements for overflows of the percolation pits. In other Site 300 facilities, these types of waste streams are discharged to septic systems. If an overflow occurs, it is sampled and analyzed to determine concentrations of any metals present. During 2006, all of the percolation pits operated normally with no overflows., and there is no evidence of any environmental impact from the operation of the percolation pits.